Light and Lighting

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Ophthalmologists and Lighting

THAT ophthalmologists ought to be knowledgeable about lighting desiderata seems obvious enough, and it is odd that only a minority of these specialists seem, in fact, to be sufficiently interested in lighting requirements and in promoting their observance in practice. The lively interest in this matter maintained for nearly half a century by the doyen of ophthalmology in this country, Sir John Herbert Parsons—to whom we take this opportunity of offering our congratulations upon his now imminent 82nd birthday—is in marked contrast with—as he said himself but a few years ago—" the apathy of ophthalmologists." It is encouraging, however, that the Executive Committee of the recent International Congress of Ophthalmology should have arranged for a lighting exhibition to be associated with the Congress. It may be hoped that this Exhibition—described elsewhere in this issue—will have stimulated a wider and deeper interest in the subject of lighting among those whom we are entitled to expect should be able to tell us what is best for our sight. Preventive ophthalmology has to do with lighting suitable for the comfort and efficiency of the eyes, and surely ophthalmologists should not lack interest in and knowledge of the conditions of suitable lighting.

Notes and News

Fittings Design

A couple of issues back we ventured a brief comment in this column on the subject of fittings design, being prompted at that time by an exhibition then running in London. The comments were provocative enough to bring forth a constructive letter from a fittings designer which appears in the correspondence column of this issue.

In insisting that we cannot imagine the circumstances under which we could possibly live with some of the fittings which are now being produced, we do not thereby support the sham or useless ornamentation. The aesthetics of any fitting is largely a matter of personal taste, but there are a lot of people who will accept anything if some enthusiastic salesman persuades them that it is just the thing they want. People can, of course, be educated to higher standards, but on the question of lighting fittings it will take some time. As our correspondent says, the efforts of the C.I.D. are at least arousing some interest and getting people to think about the subject. There does, however, seem to be a feeling that the C.I.D. *are* saying "you will have this" in certain fields of design, though they do not yet appear to have reached that stage with regard to lighting fittings. At the same time, if fittings which can be subjected to the criticism which we quoted in our previous note are given the blessing of the C.I.D., how much more are the general public likely to accept them without question?

We don't doubt that there are people in the fittings industry who know their job inside out, but unfortunately it would seem that too many lighting fittings are being designed (?) by those who have had little or no experience of the subject. It seems to have been assumed that because a man can design the label to be stuck on a jam jar he is capable of designing anything. A fresh outlook or new ideas can be helpful, indeed are essential in these days when we hardly know what light sources are likely to be available to-morrow, but when it comes to the design of lighting fittings designers from outside the industry too often forget the primary purpose of the object they are designing.

Before leaving this subject we would say that our comments have been made with the object of being helpful—and if, as a result, we are favoured with readers' views on the subject, so much the better.

Lighting and Contractors

Does the electrical contractor who carries out lighting work need to know anything about lighting? We should have thought the answer was yes. But apart from the few enlightened ones it seems that the contracting fraternity are interested in lighting only in as much as it provides some pieces of gear and apparatus which have to be strung up on wires. With quite a number of jobs this is no doubt all the contractor has to do. But there are surely hundreds of contractors up and down the country who do, in fact, design lighting schemes; small schemes perhaps, a matter of two or three lamps in a small shop or office, but nevertheless, lighting jobs which can be at fault through insufficient knowledge of the principles of good lighting. We flatter ourselves that they would be better informed if they looked through the pages of this journal occasionally.

I.E.S. President's Address to B.M.A.

It is unusual for the British Medical Association to invite speakers from other professions to address them at their annual conference and it is with particular interest, therefore, that we noted that Dr. J. N. Aldington, President of the I.E.S., had been invited to speak to the medical profession on Radiation, Light and Illumination at their recent conference.

Opening with some remarks on the functioning of the eye Dr. Aldington said that because the eye had evolved through many ages under continuous radiation no doubt the structure of its various parts and in particular the nerve endings responsible for visual perception, was related to the continuous radiation from the sun. It was also true, however, that from the beginning of time the human eye had been subjected to only sections of the visible spectrum when it saw colour. It was this fact which allowed the lamp research physicist to believe that if in the course of the evolution of practical light sources they had to produce and put before the public lamps giving discontinuous spectra then no harmful results would thereby occur.

It had been very much in mind, however, that the possibility might exist of short term or long term damage to the visual mechanism if the eye were continuously irradiated for long periods by virtually monochromatic light. Sufficient time had now elapsed, however, to make it appear probable that there were no harmful effects. Indeed, some observers had reported an increase in the ease of seeing under the light of, for example, the sodium lamp or the high-pressure mercury lamp.

The next part of the talk dealt with the sensitivity curve of the normal eye under photopic conditions and the relation of the photopic curve to lamp design problems was illustrated by discussing the changes in the energy distribution from an incandescent source with increased temperature and later by a similar comparison with the changes which occur in the mercury spectrum with increased pressure.

With the incandescent source it was shown that the peak of the energy distribution moved in the direction of shorter wave length with increased temperature, whereas in the case of the line spectrum of mercury increased arc temperature caused by increased pressure and current density resulted in a shift from the resonance radiation at 2,537 Å to the excitation preferentially of lines in the visible spectrum and ultimately in the infra red region. These general phenomena were then discussed in relation to the efficiency of light sources.

Mention was made of developments in xenon filled flash tubes designed specifically for the photography of certain conditions of the eye and in connection with fluorescent lamps mention was made of the fact that British lamp makers employ halo-phosphate powders which do not contain beryllium. An attempt was made to put into proper perspective the medical effects of beryllium which have been highly exaggerated in certain sections of the Press.

Dr. Aldington also discussed the relationships which had been found to exist between illumination levels and the incidence of fatigue. The importance of providing lighting intensity at the working plane was mentioned as well as some of the recent work on background brightness.

We are very pleased to see this interest by the medical profession in lighting. We lighting people are perhaps a little too liable to think that everyone must be interested in our subject and that with the controversy which seems to follow the introduction of any new light source the medical people should know more about lighting than they do. However, we feel that the doctors must have quite enough to do in keeping up to date with their own subjects, and the fact that they invited a contribution from the lighting industry is all the more encouraging.

The choir of Beverley Minster. The main lighting of the Minster is by fluorescent lamps; the choir is lighted by six special tungsten fittings.

Fluorescent Street Lighting in Belgium

The use of fluorescent lamps for public lighting is comparatively new and street lighting engineers have anxiously awaited information on performance and on the economic aspect. The following article, though referring only to installations in Belgium, is therefore, of considerable interest.

By A. BOEREBOOM*

In Belgium, as in many other countries, street lighting by fluorescent lamps is becoming quite extensive. The more the public see of this new method of street lighting, the more widespread its application is becoming. At present there is even quite a craze for these new light sources and, in the modernisation of lighting installations in several towns, more and more fluorescent lamps are being used. Whilst it is true to say that these lamps are being used mainly for street lighting in built-up areas, there is also a tendency to use them on roads outside built-up areas, particularly on the main roads.

All the installations which have been made are relatively recent and no decisive result can yet be drawn from these trials. It is, nevertheless, interesting to comment on these different installations.

Lamps and Apparatus

The lamps used are generally of the 40-watt type though occasionally one comes across installations where 30 or 20-watt lamps are used.

The lamp characteristics are given in Table I.

The characteristics given are the average values guaranteed by the manufacturers. These lamps, which are specially made for public lighting, are guaranteed to start at a temperature of −15 deg. C. with a voltage variation of ± 8 per cent.

The starter switch is generally of the thermal type. The electro-magnetic starter

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TABLE I

LAMP CHARACTERISTICS

Rating of lamp	40 watt
Rating of lamp with gear	48–50 watt
Length of lamp	1,20 m.
Initial light output	2,300–2,400 lumens
Nominal light output after 100 hours	2,100–2,300 lumens
Colour temperature	3,500 K
Fall off in light output after 2,000 hours (with reference to nominal flux)	18%
Luminous efficiency	45–50 lm/w
Guaranteed life of lamp	2,000–3,000 hours
Power factor	0,82–0,85

is also beginning to be used. Plastic bi-pin holders are used, the contact to the pins of the lamp being made by two flexible brass strips. The lamp is fixed by rotation of the lamp through 90 deg.

Fittings

The two types of fittings most frequently used are known as the ordinary type and the reflector type.

The ordinary fitting consists of a frame forming a roofing in stainless light alloy, the lighting apparatus being attached to this by means of insulating and anti-vibrating mountings. The diffuser is formed by a moulded "Perspex" sheet attached to the fitting by means of bolts which make for easy mounting. The diffuser can be either in clear or opal material. This type of fitting (Fig. 1) gives an all round distribution of light.

In the reflector type of fitting, on the other hand, the beam is directed at an angle of about 70 deg. above the vertical, the uniformity of light being thereby much improved. One of the fittings of this type,

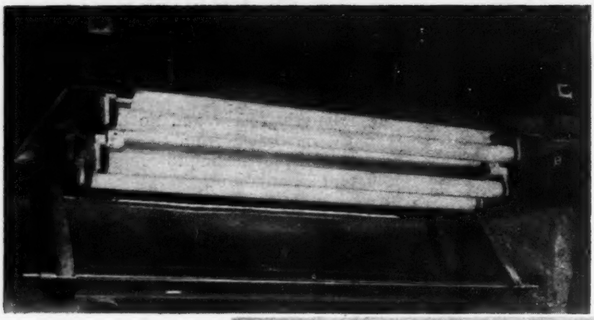


Fig. 1. Ordinary type of fitting housing four 40-watt lamps with a clear "Perspex" covering.

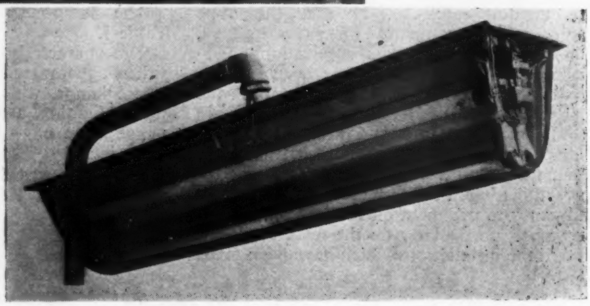


Fig. 2(a). Reflector fitting housing three lamps.

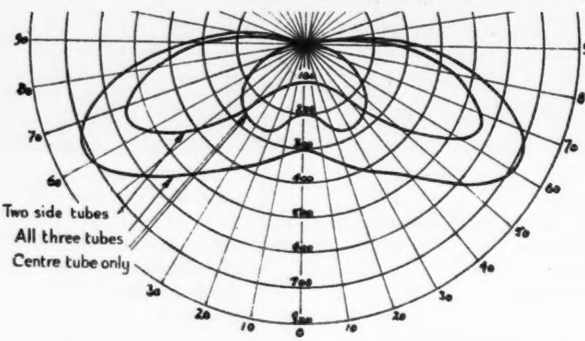


Fig. 2(b). Polar curves of reflector type fitting.

Fig. 3. At Charleroi, a staggered arrangement using ordinary type of fitting housing three 40-watt lamps with an opal diffuser. Mounting height 7·5 metres, spacing 25 metres.

recently put on the market, is constructed round a tubular main support of a strong light alloy which ensures the complete stability of the apparatus. This support has two lateral flanges of aluminium carrying the reflectors, the lamp holders and the starters. The suspension of the fitting is achieved by iron collars clamped onto the

Fig. 4. An installation on a circular road in Charleroi, using ordinary type of fitting housing two 40-watt lamps with an opal diffuser. Units are arranged on either side of the road with a spacing of 35 metres; mounting height 9 metres.

Fig. 5. Daylight view of installation shown in Fig. 4.

wind has been proved by tests in a wind tunnel. For a wind pressure of 125 kg. per square metre the force exercised by the wind on the reflector fitting is 31.5 kg. The total weight of the reflector fitting is 20 kg. as against 25 kg. for the ordinary type.

Arrangement of Light Sources

In the narrow streets in built-up areas, the fittings are generally suspended in the centre of the road by means of suspension wires fixed to the houses. The height of the suspension varies from 8-9 metres with spacings of 30-40 metres according to the type of fitting. The illumination thus obtained is very even and the pavements as well as the front of the houses are suitably lighted.

In the larger streets the staggered arrangement is used. Fig. 3 illustrates such a mounting. The height is 7.5 metres and the spacing is 25 metres. The uniformity of light is good and the centre of the road is adequately illuminated.

Fig. 6. (*right*) Installation on a promenade at Huy. Ordinary fittings with two 40-watt lamps. Spacing 25 metres; mounting height 6 metres.

support. The auxiliary gear fits into a removable drawer, which in turn fits into the interior of the tubular support. Electrical contact is made by means of a pin which ensures the joining of the accessories to the cabling from the lamps to the power supply. The parabolic reflectors are in polished anodised aluminium. The fitting is completed by a shaped aluminium roof and a protective hood in "Perspex" which is detachable and which can be swung from one side to the other. Fig. 2 shows the reflector type of fitting.

These fittings can be supplied with two, three or four lamps for the first type and two or three lamps for the second. In both types the inside of the lanterns is sealed from the outside Their resistance to the

On bends the method of mounting is either unilateral or with lamps mounted on both sides and down the centre island. The lamps are mounted on metal or concrete poles. The mounting height is 9 metres and the spacing is at intervals of 35 metres. Fig. 4 shows one of these installations.

It should be noted that, in contrast to the general practice in England, lamps fixed on poles or brackets on walls are not placed horizontally; they are almost always slanting at 20-25 deg. on the horizontal so that they project a little more light towards the centre of the road. The photometric readings show that this type of mounting results in a slight improvement in the lighting of the axis of the road. Fig. 5 is a daylight view of the installation illustrated in Fig. 4

showing the characteristic sloping of the lamps.

Sometimes the lamps are placed horizontally and parallel to the axis of the road. This is the case in Fig. 6 which shows an avenue in Huy. The presence of large trees was partly responsible for this type of mounting. The illumination, less even than in the preceding arrangements, is nevertheless adequate and in addition side paths for pedestrians as well as the tree branches are lighted. The mounting height is 6 metres and the spacing is at 25 metres.

Light Distribution

Results obtained with the fittings described above are summarised in Fig. 7, which gives the light distributions of several typical installations. The measurements are made by means of a light meter placed at street level and in the centre of the road from the point directly opposite a lamp up to midway towards the next lamp.

Curve (1): Ordinary fitting with four 40-watt lamps with an opal diffuser—height 8 metres—spacing 36 metres—central suspension—diversity coefficient 1:7.35. This arrangement is illustrated in Fig. 8. It is an important road in a built-up area. The presence of shop windows helps to raise the average level of illumination.

Curve (2): Reflector type fitting in clear "Perspex" with three 40-watt lamps—height 8.50 metres—spacing 41 metres—central suspension—diversity coefficient 1:3.8. Fig. 9 illustrates this arrangement applied to a main road in a built-up area. The illumination may be less than in the preceding case. In comparison with the preceding case, however, it was possible to obtain quite a satisfactory result by using three lamps instead of four and by greater spacing between the units. As a result of using the reflector fitting the installation is therefore more economical.

Curve (3): Reflector type fitting in opal "Perspex" with three 40-watt lamps—height 8 metres—spacing 41 metres—central suspension—diversity coefficient 1:8.

An experiment was carried out with the reflector type of fitting to find out if the glare caused by the presence of the reflectors was troublesome in comparison with that of a similar fitting equipped with an opal diffuser. It was found that the eye hardly distinguished any difference in the glare from the fittings, though the light distribution was not so good in the second case, as is shown by the diversity coefficient. By the

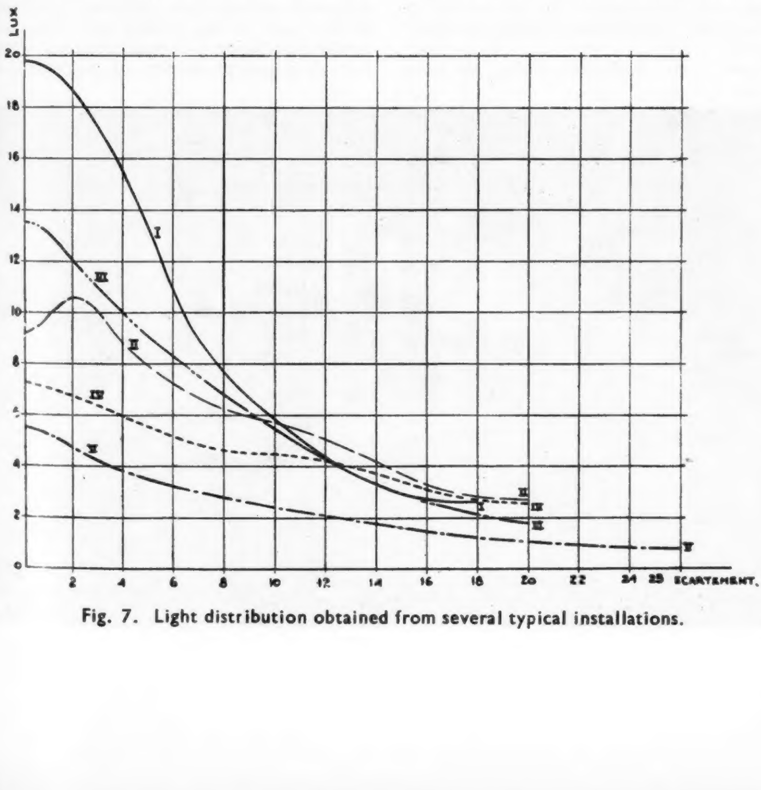


Fig. 7. Light distribution obtained from several typical installations.

Fig. 8. Installation in the Rue de la Station, St. Nicolas, using ordinary fitting with four 40-watt lamps. Spacing 25 metres; mounting height 6 metres.

Fig. 9. (*below*) Showing another installation in St. Nicolas where reflector fittings with opal diffusers are used. Each fitting has three 40-watt lamps. Spacing 41 metres; mounting height 8·5 metres.

use of a diffuser with a reflector fitting the advantages of the reflector are lost and the fitting then gives nearly the same result as the ordinary fitting with an opal " Perspex " diffuser.

Curve (4): Reflector fitting in clear " Perspex " with three 40-watt lamps—height 8.50 metres—spacing 42 metres—staggered arrangement—diversity coefficient in the centre of the road 1:2.6. This particular installation is in a quieter road, where there is a greater number of pedestrians in

TABLE II

ANNUAL RUNNING COSTS PER KM OF ROAD
No. of lighting hours : 2,000
Price per kwh : 2 francs*

	85w Sodium	125w H.P.M.V. colour corrected	2 × 80w H.P.M.V. colour corrected	250w Mixed Mercury and Incand.	3 × 40w Fluor.	300w Incand.
Nominal wattage	85	125	160	250	120	300
Actual wattage	105	137	176	250	150	300
Lumen output per fitting ...	6,500	5,000	6,000	5,000	6,600	4,400
Lamp life (hours)	3,000	2,000	2,000	1,500	2,500	1,000
Price per lamp (francs)... ...	200	228	161	163	45	39
Replacement cost of lamps per fitting (francs)	132	228	322	218	108	78
Annual cost of inspection and upkeep per fitting (francs) ...	125	150	250	175	350	250
Annual cost of current per fitting (francs)	420	548	704	1,000	600	1,200
Cost of lantern ; including gear and fixing (francs)	2,250	1,350	2,500	770	3,300	770
Depreciation of lantern over ten years (francs)	305	184	340	105	450	105
Depreciation of unit over twenty years (francs)	300	300	300	300	325	300
Spacing (metres)	32	24	31	24	32	24
Lanterns per km	31.2	41.6	32.3	41.6	31.2	41.6
Lumens per km (thousands) ...	203	208	194	208	206	183
Annual running cost per lantern (francs)	1,282	1,410	1,916	1,798	1,833	1,933
Annual running cost per km (francs)	40,000	58,500	62,000	75,000	57,500	80,000

*Approximate value of the Belgian franc: 140 francs = £1.

proportion to vehicles. While the diversity is good in the centre of the road, it is less good on the pavements, although the result is reasonably satisfactory. Fig. 10 shows this installation.

Curve (5): Reflector fitting in clear "Perspex" with two 40-watt lamps—height 8 metres—spacing 50 metres—unilateral wall bracket arrangement—diversity coefficient 1:8. This is in a quiet road used mainly by pedestrians. The lighting on the pavements is quite adequate and the installation is very economical because of the low rate of consumption of electric power and because of the wide spacing between each unit. This installation is shown in Fig. 11.

Costs of Different Lighting Installations

The growing vogue for lighting installations using fluorescent lamps is due in the first place to the quality of the lighting produced by these lamps, the colour closely resembling daylight, and also because of the relatively reduced costs of these lamps.

Whilst it is difficult to make an objective comparison of the several kinds of lighting installations, one can nevertheless try to classify them according, for example, to the annual working costs for one kilometre of road illuminated by each type of source.

The sources most used in Belgium for public lighting are:—

(a) 85-watt sodium vapour.
(b) 125-watt H.P.M.V. (colour corrected).
(c) 80-watt H.P.M.V. (colour corrected).
(d) Mixed (combination of mercury and incandescent) 250 watt.
(e) 40-watt fluorescent.
(f) 300-watt incandescent.

Table II gives the annual working costs of

Fig. 10. A road in St. Nicolas, showing the bilateral arrangement. The reflector fittings, each holding two 40-watt lamps, are spaced at intervals of 42 metres at a height of 8·5 metres.

Fig. 11. *(right)* Rue de la Jonction, St. Nicolas, where the installation consists of reflector fittings each housing two 40-watt lamps. The arrangement is unilateral, the mounting height is 8 metres and the spacing 50 metres.

one kilometre of road illuminated by each of these sources. The figures shown are average values. The table is based on an annual running time of 2,000 hours with a cost of current of 2 francs per kwh. A comment is necessary on the subject of the supervision and annual maintenance cost of an installation. These figures include the cost of regular and periodical inspection of the installation, time control, cleaning and maintenance of the fittings, replacement of lamps (excluding the value of these lamps), painting of metal parts, depreciation of maintenance materials, the upkeep of the repair workshops, general costs, etc. These costs vary from one installation to another. The figures quoted relate to a large installation for which a special maintenance staff is employed.

The depreciation of the lantern is assumed to be over 10 years, compound interest being at 6 per cent. The depreciation of the unit, including the columns, cables, supply lines, control gear, etc., is assumed to be over 20 years. For fluorescent lighting, the figure stated is a little higher than the others because it is admitted that the installation is more costly, due to the weight of the fitting, which necessitates specially reinforced columns, brackets and transverse suspensions, etc.

The spacing between the units is chosen in order to obtain, with the different types of lantern, an average illumination of about 0.4 $lm./ft.^2$ (four lux) for a mounting height of 7.5 to 9 metres.

The comparison of the different sections lighted by means of the different sources shows that the number of lumens per kilometre is very much the same and the sections are comparably illuminated.

On looking at the table it will be seen that the most economic installation is that using sodium vapour lamps which works out at about 40,000 francs per kilometre. Next, at more or less the same cost, come the mercury 125-watt and fluorescent installations which have an average cost of 60,000 francs, being 50 per cent. more than the figures for the sodium vapour lamps. Then, lastly, come the incandescent and the

mixed lamps, the annual running costs of which are double those of the sodium lamps.

In order to calculate the variation in cost in relation to cost per kw. and in relation to number of hours of lighting, graphs (Figs. 12 and 13) have been prepared. These graphs show that, as far as the cost per kw. and the duration of the lighting are concerned, sodium lamps remain the most economical; fluorescent lamps compare favourably with mercury vapour lamps while installations using incandescent lamps are always the most costly.

In Belgium, the sodium vapour lamp is, for the most part, used mainly on traffic routes. It is essential that the traffic should enjoy the same complete security when travelling quickly at night as it does in the daytime and that it should not be necessary for the driver to use his headlights. These lamps are used on communicating roads in the country and also in built-up areas on circular boulevards and main roads. The nature of the lighting serves at the same time to guide the traffic.

The graphs concern the annual running costs and show that fluorescent lamps can be used to advantage in built-up areas, in roads where the colour-rendering has to be considered and where the carriageways, pavements and fronts of houses all have to be illuminated. While the initial costs of the installation are generally higher than those for other sources (mercury and incandescent), the annual running costs assessed over a period of ten years, including the depreciation of the installation, are no higher than those for mercury vapour lamps and appreciably lower than those for incandescent lamps.

Principal Installations In Belgium

Fluorescent lighting is relatively recent in Belgium. The first experiments in public lighting by this means were in 1947. At that time we were influenced by the American statement that the functioning of the fluorescent lamps became unreliable when the temperature fell below 5 deg. C. One of the main objects, therefore, of the first trials was to see how the lamps behaved in winter when the weather was cold, and after some experiment it was found that the lamps would operate at a temperature as low as −10 deg. C. While it is true that the luminous efficiency is greatly reduced when the temperature is lowered, nevertheless, the lamps light even when the weather is below freezing point. It is true that the winter of 1949-50 was relatively mild and that the observations were made only on a few nights when there was frost. There is reason, therefore, for prudence before using these lamps on a large scale.

Our experience of the maintenance, the upkeep and general behaviour of fluorescent street lighting installations over a long period is also very limited. Up to the present it has not been possible to determine precisely such matters as the cost of lamp replacement, average length of life, cost of cleaning of fittings and the resistance of lanterns and fittings to atmospheric conditions.

However, as stated, fears expressed at the outset regarding the subject of the weight of fluorescent fittings and of their effect on the suspension cables, especially under wind pressure, seem to have been much exag-

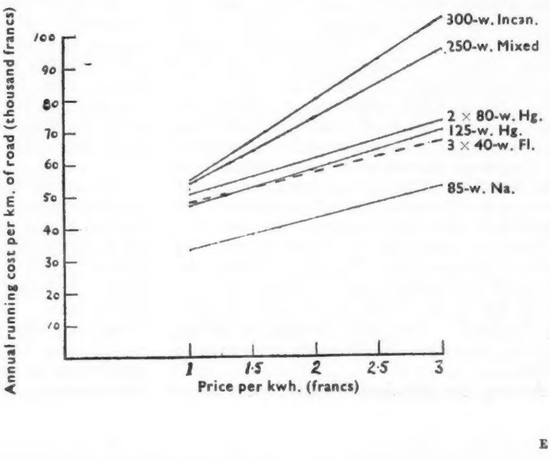


Fig. 12. Showing annual running costs per km. of road with varying cost of current, hours of lighting being fixed at 2,000 per annum.

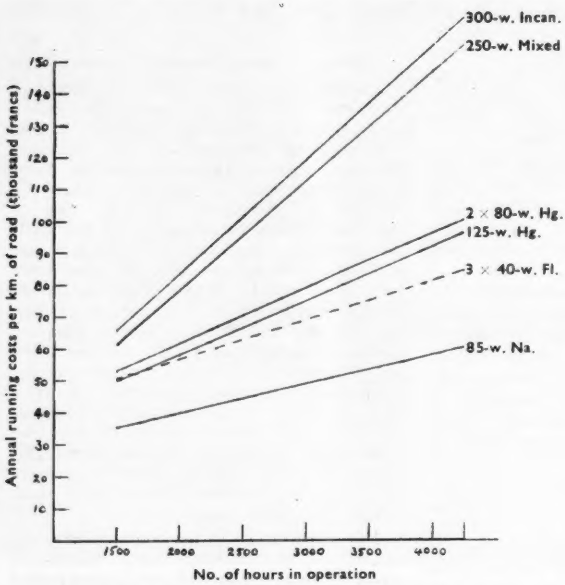


Fig. 13. Showing annual running costs per km. of road with varying hours of operation, cost of current being fixed at 2 fr. per kwh.

gerated. Up to now few difficulties of this nature have been encountered. On the contrary, the large dimensions of the fittings do not appear to cause any inconvenience. The public are getting used to them. Relying, therefore, on prudent expectation, fluorescent installations are expanding more and more. Among the principal installations, first place must be given to the lighting at Charleroi, which is entirely by means of fluorescent lamps. The fittings house two, three or four 40-watt lamps. The fittings are the ordinary type without reflectors, and 95 per cent. of the fittings are equipped with opal "Perspex" diffusers. The mounting height varies from 6—12 metres (20—40 ft), and the spacing from 30—50 metres (100—165 ft.). About 1,500 units are at present installed in the town of Charleroi. On the main roads within a radius of five kilometres of Charleroi fluorescent street lighting is also installed. The arrangements are similar to those at Charleroi, and so far about 1,800 additional units have been put into use.

Mention must also be made of the 150 units at Soignes, the 27 units at Alost, the 14 units at Ostende and 124 units at Huy, all of which are of the same type as those at Charleroi. The total number of fittings actually installed in Belgium amounts to 4,000.

Among the principal installations now in the course of being carried out or which are being planned are:—

	Units
St. Nicolas	1,200
Sections of the Royal road through Conyde, St. Idesbald, la Panne	275
Marcinelle	600
Arlon	600
Parts of the towns of Gosselies, Boom, Brussels, Renaix, Deinze, Eghezee	400

Arrangements are thus being made for the installation of a further 3,000 units which means that by the end of this year there will probably be over 7,000 units in operation. The large majority of the units installed are the ordinary type with an opal diffuser. The price of the fittings varies from £15—£25 according to the type.

Conclusion

The above details show the great importance of fluorescent lamps in public lighting. Several towns have no hesitation in lighting all their streets and public highways by this means. It is still too early to judge how these installations will behave under atmospheric conditions, and it seems premature, with the little experience acquired up to now, to make any binding decision concerning a wide-scale adoption of these light sources. The costs of the first installa-

tion of these large units are still relatively high, but the running costs are advantageous and very much less than those for incandescent lamps. It would appear that still further progress could be made by reducing the size of the fittings and lamps, lengthening the life of the lamps, by research for fittings which would have a perfect resistance to atmospheric conditions and which are easily maintained. It is possible that, under these conditions, the use of these lamps for public lighting would increase.

I am grateful to the following firms for the documents and photographs with which they have assisted me: Ateliers de Constructions Electriques de Charleroi, Societe Anonyme Belge Philips, and Societe Anonyme de Constructions Schreder.

Colour Group Visit to Kodak's

Some 30 members of the Physical Society Colour Group paid a very interesting visit to the Works and Research Laboratories of Kodak Limited at Harrow on Wednesday afternoon, June 28. Naturally, the emphasis was on colour material and its processing, but a short time was spent in the "D & P" department where the developing and printing of amateurs' (and others') efforts to record in monochrome that charming landscape, or to capture the spirit of the moment, was in progress. Several of the visitors remarked on the fact that these operations were not as automatic as might, perhaps, have been expected. It was clear that a good deal of individual skill and experience was called into play in an effort to get good results or (alas, not infrequently) to make the best of a bad job. Quite elaborate precautions were taken to ensure that Mr. A's snaps were not returned to Mr. B, but it was tempting to try to picture the endless complications that might ensue if, by chance, this system should break down at any time.

It was, of course, useless to attempt to show visitors any of the sensitizing processes, and even in the department which dealt with the examination and packaging of paper it was difficult to follow what was going on under the small patches of dim red or greenish light which provided the only illumination in an otherwise completely blacked-out building.

Part of the rather complicated processes involved in the preparation of copies of a colour film was shown, and it was explained that, as colour film was, in essence, a reversal film, the latitude permissible was very limited indeed. This fact was brought out at several stages in the tour, and it is probably a lack of appreciation by the amateur that colour film cannot cope with anything like the range of luminance which can be faithfully rendered by monochrome film that is responsible for the startling failures that sometimes occur. Even a slight over- or under-exposure will result in a noticeable change of the colour-balance, and this was, in fact, remarked during a very interesting demonstration consisting of an original movie colour film projected side by side with a copy. In ordinary circumstances both would have been quite acceptable to the ordinary viewer, but when seen side by side there was a noticeable difference, one appearing generally rather greener and the other rather redder than its neighbour. An extreme example of the same effect was shown by a visitor during the tour of the research laboratories. He produced a colour photograph of a spectrum consisting of a series of intense lines on a moderately bright continuum, and it was interesting to see how the lines in the green part of the spectrum appeared a bright yellow due to their gross over-exposure.

In the research department, Mr. R. W. G. Hunt, who was responsible for organising the visit, showed the work in progress on those aspects of colour vision, particularly colour adaptation, which affect a viewer's appreciation of a colour reproduction. The more routine work of spectrophotometry and densitometry was also shown, and an instrument of considerable interest was one of the first Hardy recording spectrophotometers to be made.

Finally, the most elaborate demonstration was that of making colour prints by the dye-transfer process. In brief, this involves the preparation of four negatives from either the original object or from the colour transparency. Three of these negatives are taken through red, green and blue filters respectively, the fourth being used to reduce excessive contrast. The "red" negative is treated in such a way that the unexposed parts absorb a blue dye which is, in fact, complementary to the red of the filter. This dye is then transferred to a paper and a similar process is carried out with cyan and yellow dyes transferred from the negatives taken with the other two filters. Great care is taken to ensure precise register, and the result is a colour reproduction on paper of the original, whether it be a coloured object or a transparency. Even with the negatives ready prepared, the process of making a print occupied over 30 minutes, and it soon became abundantly clear that the process was one that could only be undertaken by a professional or an extreme hard-bitten amateur. Tea concluded a most enjoyable and instructive visit, and the thanks expressed by the chairman of the Group, Dr. Stiles, were heartily echoed by all those who had been privileged to participate.

The National Institute for Medical Research

This article describes the natural and artificial lighting at the National Institute for Medical Research at Mill Hill which was opened earlier this year.

The new National Institute for Medical Research at Mill Hill, which was formally opened by His Majesty the King, accompanied by the Queen, on Friday, May 5, 1950, is by far the largest of its kind in the British Commonwealth. The building was designed in 1936. By 1940 construction of the outer shell had been completed, but owing to the war it was not until 1946 that work could be commenced on the interior and on equipping the building for its special purpose. The space and facilities for all types of laboratory research in medical science which the Institute provides will stand comparison with any in the world. In a building designed for such important and often visually exacting work it is to be expected that effective provision will have been made "for securing and maintaining sufficient and suitable lighting," both natural and artificial. A visit to the Institute shows that this expectation is realised, and a brief description of the lighting of the building cannot fail to be of interest to readers of this journal.

Natural Lighting

The building, which has been designed for the Medical Research Council by Mr. Maxwell Ayrton, F.R.I.B.A., is situated on high ground, where none of its surroundings offers a high angle of obstruction. The building consists of a central block of seven stories, with two obliquely set wings at each end rising to a height of three stories from

Fig. 1. Exterior view of the new National Institute for Medical Research at Mill Hill, showing how the building is designed for good interior daylighting

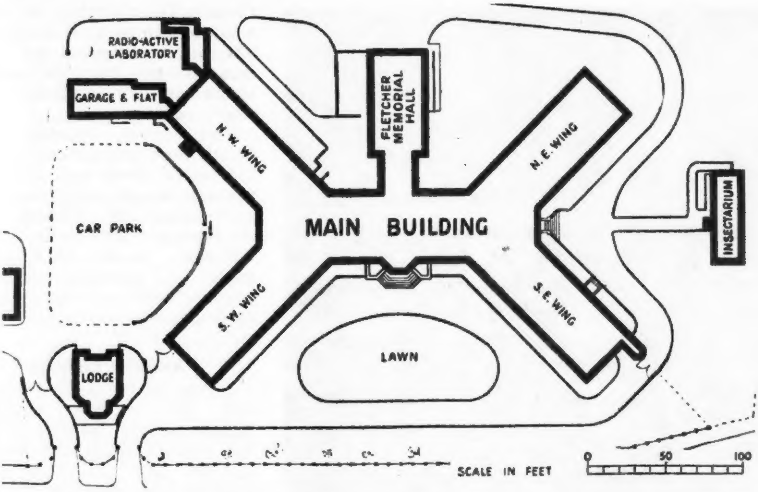
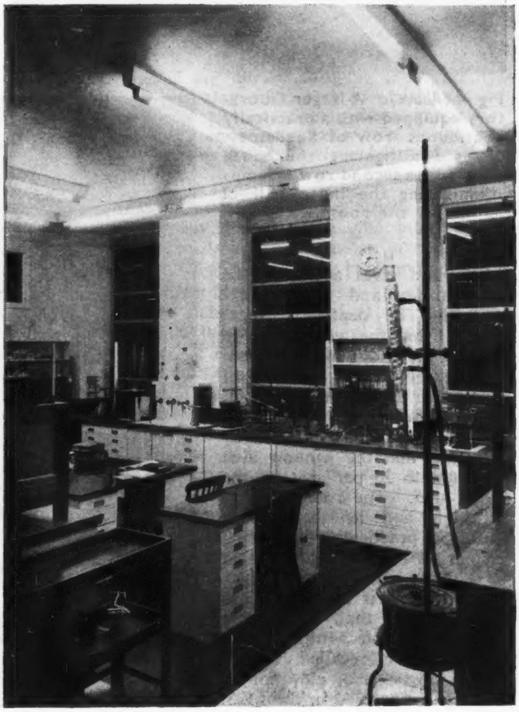


Fig. 2 *(Above)*. Plan showing arrangement of the building. Fig. 3 *(Right)*. A typical laboratory in the Institute showing the ceiling-mounted fluorescent lamps arranged for good general lighting of the desks and benches. The illumination is between 30-40 lm/ft^2.



the ground level at the front. In plan the angle between each of a pair of wings is 90 deg., so that if the two pairs of wings were directly joined, instead of being linked by the central block, the floor plan of the first three stories would be cruciform. Figs. 1 and 2 show the arrangement described. As there are windows of generous area in all the external walls, this design has the great advantage of allowing excellent penetration of daylight to all rooms. Owing to the fall of the ground towards the north and north-west, certain parts of the building have also well-daylighted basement and sub-basement rooms.

The central block and each wing has a width of about 40 ft. On the first three floors a central corridor divides each

Fig. 4 *(Above)*. A larger laboratory equipped with a practically continuous row of fluorescent lamps for lighting the bench area, with a second row of lamps illuminating the inner half of the room.

block and gives access to the laboratories and other workrooms. The depth of these rooms from the windows is 16 ft. and the width of each room is 8 ft., or some multiple of this unit. Each 8 ft. by 16 ft. floor space unit has one window of dimensions 8 ft. by 4 ft., so that the window area is equal to 25 per cent. of the floor area. The rooms are 11 ft. high, and as the window head is practically at ceiling height its angle of elevation at a working point in the centre of the room is about 45 deg., and is more than 26 deg. at the most remote working point. It may be recalled that a minimum angle of elevation of 24 deg. is specified in the I.E.S. Code. The spacing of the windows can be seen in Fig. 3. The central corridors are illuminated by borrowed light supplemented by artificial light where necessary.

The library occupies the fourth floor and mezzanine of the central block and, like the canteen on the fifth floor, is cross-lighted by windows in the front and back walls of the building. In the library the angle of elevation of the window heads at the central reading tables is about 45 deg.

Artificial Lighting

Except in the animal house and the corridors artificial lighting in the Institute is by hot cathode fluorescent tubes, and the fact that these are used in this centre of medical

Fig. 5 *(Below)*. View showing method of lighting the corridors by means of tungsten lamps in "Ultralux" enclosed fittings.

research, after a satisfactory full-scale trial for some years at the Medical Research Council's administrative headquarters in Westminster, should be reassuring to those who may still be under the impression that fluorescent lighting has harmful effects.

The lighting was installed by Messrs. Troughton and Young, Ltd., and the special fittings used were made by Messrs. Troughton and Young (Lighting), Ltd., and designed by them in collaboration with the architect. The laboratories provided an interesting design problem in that the demand was for a simple fitting which would involve the minimum of wiring and would enable sufficient illumination to be obtained on the work-benches, which are fitted along the window wall and also, in most cases, along each wall, as shown in Fig. 3. As fluorescent lamps of various lengths were to be used, it was decided to mount them in line following the contour of the benches. In some of the larger rooms additional independently mounted lamps are used to obtain a suitable distribution of light, giving adequate illumination over working areas situated towards the back of the rooms.

Fig. 6. A view of the library showing the specially designed general lighting units, each of which utilises 19 40-watt fluorescent tubes. Special fluorescent tube units are mounted under the gallery to illuminate book stacks and reading tables. The level of illumination is 20 lm/ft^2.

A standard section fitting, incorporating a wiring trough, was designed for ceiling mounting, and various lengths of this section were made. By combining suitable lengths, together with mitred corner pieces and jointing sleeves, the whole of the lighting scheme was built up with a minimum number of parts. The continuous wiring trough so formed enabled the installation work to be carried out very simply, and pull-cord switches have been incorporated in the jointing pieces where required. A suitable number of outlet sockets is provided in the laboratories to enable special local lighting to be used when required, e.g., for microscopy.

The animal rooms are lighted by tungsten filament lamps in standard " Ultralux " fittings, and more than 200 similar fittings are used for the corridors and staircases. The canteen is lighted by pendant " Tubalux " fittings, each equipped with two fluorescent lamps. These fittings harmonise well with the design of the interior, and the installation provides an average illumination of 7-8 lumens per square foot.

Special fittings are used in the library, the Fletcher Memorial Hall, and the entrance hall. The general lighting of the library is effected by means of five large pendant fittings, each of which houses nineteen 40-watt fluorescent lamps. The metalwork of the fittings is bronze relieved with lacquer gilt mouldings, and the glazing is with obscured stippolyte and reeded glass except at the top, where there are clear glass panels for passing upward light. Between the beams under the side galleries fluorescent lamps are mounted to illuminate the bookstacks. These lamps are in fittings harmonising in design with the main pendants.

The hall on the ground floor, built to commemorate Sir Walter Fletcher, is illuminated by means of twenty-four 200-watt filament lamps, which are concealed from view in twelve fibrous plaster wall brackets.

Colour-Matching Tests

The following is a report on an exhibition of colour-matching lamps, held at Leeds by the Wool Industries Research Association, with the assistance of the I.E.S. and the lamp makers. The conclusions drawn from the comments of visitors and from a colour-vision test conducted at the exhibition are discussed.

Introduction

The interest shown in the exhibition was most gratifying. Representatives of some of the large retail stores in Leeds and London as well as clothing manufacturers were among the visitors, as were also those of other colour-using industries.

The exhibition showed all the British colour-matching lamps currently available; two "daylight" lamps not recommended by the makers for colour matching were included for comparison purposes. In addition one of the best-known American colour-matching lamps was shown primarily for the benefit of exporters whose customers may use such a lamp. There were three main types, namely, modern versions of the filament lamp with filter glasses, fluorescent colour-matching lamps and units consisting of combinations of special fluorescent and filament lamps mounted behind a diffusing screen. The American lamp was of the first type.

Visitors were provided with various sets of coloured patterns for assessing the comparative merits of the different lamps, and they were also invited to bring their own samples for this purpose. A form was supplied so that they might record their comments on the lamps and samples, and we have used these records to compile the present report.

One section of the exhibition was set aside for making a survey of the variations in normal colour vision associated with the fairly common experience among dyers that some people see "redder" than others. During the course of the exhibition lectures were given on "Artificial Daylight" and "Variations in Noral Colour Vision."

Comparison of the Different Types of Lamp

There were indications that there is a definite preference for the modern filtered tungsten lamps and the combination fluorescent and filament lamps, as compared with the straight fluorescent matching tubes. There is also a marked preference for those providing a wide area of well-diffused light. These preferences are in accord with expectations deduced from theoretical considerations.

On analysis of the forms it became evident that where all the patterns in one set were dyed from the same basic recipe, differing only slightly in the amount of one component, everybody found the type of difference under all the lamps which was expected from the change in recipe. Generally the extent of the difference was not indicated, and it would appear that the variation between the lamps was little greater than that between individuals; the latter variations being due partly to small differences in colour vision, but also to difference in practice in colour matching. In most cases it was not possible to determine the training of the person filling in the form.

In one of the sets the standard was dyed from a different basic recipe from the other patterns. Similar types of sample were also brought in by some of the visitors. These materials were more useful in indicating the differences between the various lamps. In most cases there was very little difference between the various so-called colour-matching lamps, but those lamps which did not claim to be suitable for accurate colour matching led to very different assessment of the colour differences between the patterns and the standard. There were, however, cases where the fluorescent type of colour-matching lamps led to slight variations from overcast daylight in the assessment of colour difference in the opposite sense to those produced by ordinary filament lighting, but to a much less degree. This could be attributed to the known deficiency

of these lamps in light at the extreme red end of the spectrum, and was only shown in a few cases.

There were also minor discrepancies between the assessment of colour difference under the light of the different fluorescent colour-matching lamps, but it was impossible to say which gave the best correlation with overcast daylight.

This analysis accords with the preferences expressed by visitors, and it would appear that for most purposes all the colour-matching lamps would prove satisfactory in practice, although in exceptional cases, mainly where the patterns have a high reflection in the extreme red, the straight fluorescent lamps are less satisfactory than those using a combination of fluorescent and filament lamps or the filtered light from a high-wattage filament lamp.

The general conclusion is thus reached that while the blended lamps and filtered tungsten are the safest to use in difficult cases, the fluorescent colour-matching lamps are quite satisfactory in the majority of cases, and reasonably so in all cases.

Although the lamps were housed in separate booths in order to separate com-

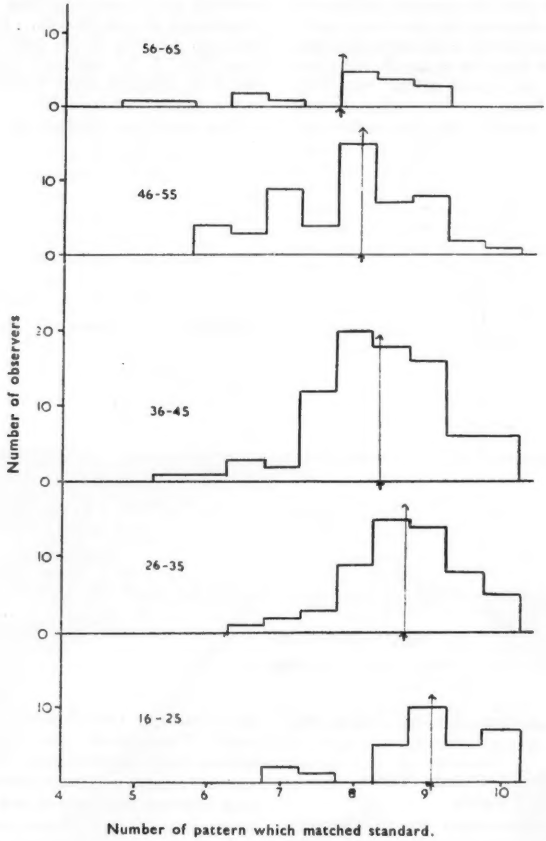


Fig. 1.

pletely the light of the different types of lamps, this would not be recommended for general practice. In order to avoid sudden changes in adaption of the eye it is desirable that the general light of any room in which colour matching is performed should not differ too greatly in quality or intensity from that used for matching. The colour-matching fluorescent tubes would appear to be very suitable for the general lighting of the office since they are no more expensive to install than ordinary fluorescent lighting. When one of the filament or combined types if preferred for the actual colour matching, the difference between the general and matching light would then be sufficiently small for any interference to be of negligible importance.

Analysis of Colour Vision Survey

The object of this survey was to determine the extent of the variations in normal colour vision of the type associated with the remark that A sees redder than B. These variations are usually attributed to differences in pigmentation of the eye. The practical importance of these differences is that their effect is very similar to that of changing the lighting from north sky to direct sunlight and may be even greater in magnitude, so that in matching samples dyed from different recipes, different observers may produce matches differing as much as one person would produce in different types of lighting.

The test used was based on this observation and consisted of matching a long strip of material with one of a series of samples adjacent to the strip; the patterns of the series were numbered from 1 to 13, varying in shade from a greenish hue at 1 to a purplish at 13 and matching the long strip somewhere in the middle. For one individual the position of the best match changed from No. 3 in ordinary electric light to No. 8 in artificial noon sunlight and No. 12 in artificial north skylight.

This card was illuminated with artificial noon sunlight (the B lamp of the International Commission on Illumination) and visitors were asked to state the pattern giving the best match, and to comment on the difference between this pattern and the continuous strip, since the match was rarely exact. In order to assist the analysis they were asked to give their age and occupation, as it was expected that in addition to a variation with age, some standardisation would have taken place in dyehouses although the standard might vary from firm to firm.

Omitting a few cards which were returned by visitors obviously having defective colour vision, it was found that the position of the best match varied from No. 5 to

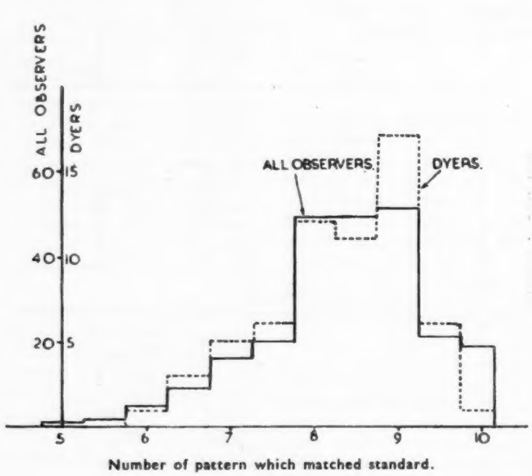


Fig. 2.

No. 11, or almost as much as between changing the lighting from noon sunlight to artificial light.

Fig. 1 shows the distribution of position of the match for different age groups. This shows that there is a definite shift of position of match to lower numbers with increasing age, corresponding to increased pigmentation. This is in accordance with the view that older people tend to see redder. It is almost certain that there is a tendency for pigmentation to increase with age although this may not always be so.

Fig. 2 shows the distribution of position of match for all the visitors and those whose cards suggested that they were regularly concerned with shade passing in connection with dyeing. The distributions are very similar except that there are relatively few extreme matches amongst the colour matchers. The variation is, however, still large and would have a considerably greater effect on colour matching that the difference between American and British artificial daylight.

Conclusion

Analysis of the data obtained suggests that accuracy in colour matching is as much a matter of choice of observer as of choice of lamp, and that the most important factor for the lamp is the distribution of energy in the different parts of the spectrum rather than the actual colour of the source. Thus, fluorescent tubes tend to be deficient in red, and this led to a preference for filament and filter lamps or combinations of fluorescent and tungsten lighting, whereas a change in colour temperature of 300 deg. K would be very small compared with observer differences, i.e., on colour-vision test it would only change the position of the best match by half the difference between adjacent samples, e.g., from No. 8 to between No. 7 and No. 8. It follows that a change in colour temperature of this order during the life of the lamp would be of less importance than the variation in energy distribution of different lamps all of the same nominal colour temperature. Proper design of fittings to give diffuse lighting over a large area would also appear to be desirable.

International Lighthouse Conference

In spite of its great importance the illuminating engineering side of lighthouses is one of the lesser-known aspects of the lighting engineer's activities. The following article briefly summarises the discussions at the recent fourth international conference

The idea of an interchange of information amongst nations on maritime signalling matters first crystallised in a meeting held in London under the auspices of Trinity House in 1929, and was so successful that further conferences were arranged every four years, being held at Paris in 1933 and at Berlin in 1937.

Over a hundred delegates from 19 countries attended the fourth International Lighthouse Conference held in France during July, where they interchanged technical information on almost every aspect of lighthouses, lightships and buoys, and other methods of signalling to mariners. Some idea of the scope of this conference will be gained from the fact that nearly 40 reports were presented for discussion.

The conference, brilliantly organised by M. de Rouville, Director of the French Lighthouse Service, was held in the Hotel du Palais d'Orsay, on the banks of the Seine in Paris, and was followed by visits to lighthouses in Bordeaux and in the Channel, where the delegates were able to see the striking way in which the French have rebuilt their lighthouses, almost all of which were destroyed during the war.

Owing to the large number of subjects to be studied the conference was split into halves, one, presided over by M. de Rouville and M. van Diggelin, chief of the Dutch Lighthouse Service, dealing largely with constructional matters, power supplies, etc., and the other, under M. Petry, Assistant Director of the French Service, and Captain Chase, Civil Engineer of the American Coast Guards, dealing with signalling and signalling devices.

The older signalling systems, of course, rely upon light and sound, but it was very noticeable that at this conference the advent of radio and radar was beginning to have its impact on lighthouse engineers. Although it was generally agreed that light and sound would continue to be used for the greater part in lighthouse work for many years to come, it was interesting to note that it was the elder delegates who were most sure about this. It was also interesting to note that the majority of the authors of papers on radio and radar were noticeably of a younger generation who, whilst admitting the complexity of their apparatus, seemed much less worried about it than their elders, and very obviously much more confident of solving their problems than were the elder generation of light and sound engineers. Whether this was the optimism of youth remains to be seen, but to one lighting engineer at least it was in marked contrast to discussions on the lighting side where the old problems of light sources and visibility still continued to attract attention.

Light Sources

It was these two questions which provided the most interesting discussions for lighting engineers, and it is very gratifying to be able to report that the British delegates were able to take the lead in describing work done in these spheres. Papers by Messrs. Bowen, Oakley, Meeks and Penny reported from various angles the experiments carried out in Britain and the discussions held between users and makers designed to determine the most suitable shapes and sizes of electric lamps for lighthouses.

As might be anticipated from the expense and complexity of lighthouse building the advent of a new source of light is unlikely to justify entirely scrapping the optical system, and, generally, new sources have to

be adapted to suit the old optics. Consequently when electric lamps of large enough power to be useful for lighthouses became a possibility after World War I, the Dutch Lighthouse Service and Trinity House asked manufacturers to design lamps with sources as similar to the original petroleum vapour mantles as possible. Many varieties of filament shape were tried, and for many years a cruciform design was the best available, but as in some of the older designs of lenses it gave a split beam on account of the large number of elements being focused eccentrically, endeavours were made to produce a shape which had a larger overall diameter and yet was as solid as possible. The problem to an electric lamp engineer is peculiarly difficult since he has to start with a long thin wire, and clearly efforts to make a thin wire masquerade as a sphere or cylinder are unlikely to succeed. One of the most attractive designs, optically speaking, consisted of three filament assemblies set 120 deg. apart in azimuth, each being composed of two filaments in parallel to form cylinders. Such a design is, of course, very difficult to make.

Another design consisted of a simple cylinder formed of two filaments in parallel, a third of four filaments in a star-shaped arrangement and a fourth of a silica cylinder which was intended to be heated to incandescence by an internal filament.

Trinity House arranged for the various designs to be tested in South Stack, Anglesey, observations being carried out over several months in order to try and determine the relative merit of the different sources in all weather conditions. Considerable difficulties were experienced in making a proper assessment of the visibility of the different lamps and the experiments were considered to be not entirely conclusive, but the general impressions reported were that the most desirable design of filament is one with uniform projected width and with the least possible gap between component limbs. It is also clear that the loss in total light occasioned from the use of a multiplicity of fine wires is a serious disadvantage and that the overall efficiency of the lamp is an important factor.

Other experiments have been carried out at South Foreland to try and determine the optimum size of filament, and for these trials lamps of cruciform filament shaps have been used both of 3 kw. and 4 kw. rating. In this case observations were only made on one night and at the relatively short range of one mile. Once again, however, the results were not conclusive, although in general terms they supported the other experiments in showing the importance of a large source and a high light output.

Whilst these experiments were going on discussions were taking place under the auspices of the B.S.I. aimed at correlating this work with other theoretical work on the same problem in the endeavour to establish a range of standard lamps which could be adapted by the majority of existing lighthouses and for all new lights. This work, of course, involved consideration of other factors than source, shape and size, as for instance, supply voltage and focusing arrangements and has culminated in the issue of BS 1546 which covers a range of lamps suitable for all types of lighthouses.

In the discussions of these papers at the International Conference it was disclosed that conditions in several other countries were markedly different. America has discarded all its old optical systems and is now using lenses of a much smaller size.

France, having had the majority of her lighthouses destroyed in the last war, has also rebuilt with smaller lenses whilst Swedish electric lights are generally of a low power (1,000 watts or less) when smaller sources are adequate. In all these territories the normal practice appeared to be to use more or less standard types of projection lamps, although in Sweden it was reported that specially frosted lamps, both projection and general service types, were quite popular, whilst in American reports the use of battery operated sources were referred to. However, there was general agreement that there probably already existed sufficient data to permit standarisation of light sources up to about 1,000 watts.

It was also agreed that further data was required regarding the requirements for large optics and several countries agreed to investigate the problem. In view of the work already done on this subject, the British were asked to act as the secretariat for the interchange of data in the hope that at the next conference a unified picture could be presented.

Amongst the many interesting points from the report of Sven Oberg (Chief Electrical Engineer of the Swedish Board) is the growing use of remote control of lighthouses both by radio and by cable. Commander Brush, United States Coast Guards, reported the completion of America's second radio controlled lightship. This fully equipped vessel of 180 tons will shortly go into regular service as an unattended lightship.

It will be controlled by a frequency modulated radio link from Sandy Hook.

Visibility

Another session of especial interest to lighting engineers was the discussions which took place on the papers by Hampton and Gough on the relationship between the international visibility code and atmospheric transmission from which they deduced a method of calculating the luminous range of lights in all types of weather.

Seamen can recognise a lighthouse by its code signal, but they also need to know its distance and the estimation of distance has always been a problem. Charts often indicate the range under weather conditions (specified by atmospheric transmission) which is quite sound theoretically, but as the measurement of transmission is rarely practicable, the information is generally of little use. Visibility is now specified by the maximum distance at which a standard object is visible and a code of distances has now been agreed internationally. Similar measurements at night are not possible since there is no general illumination to light the standard object and in consequence an artificial light is used. Moreover, in daylight an object becomes invisible due to lack of contrast, but at night because the illumination of the eye falls below a certain value (which varies over the relatively small range of two or three to one). Hampton and Gough were able to show how by knowing the daylight visibility range it is possible to estimate with a reasonable degree of accuracy the maximum range of a light of known intensity. They, therefore, suggested that a chart based upon these experiments should be taken as the basis of an international system of luminous range measurements.

In the discussion it was evident from many sides that, although data of this type would be most welcome to mariners, there was some doubt as to whether the approximations made in order to produce a simple answer were justified. M. de Rouville said that France had carried out tests on the luminous range of French lights over many years, both in the Channel and on the Atlantic coast, with very varying results. Generally, it was their experience that the observed results were lower than indicated by theory and they therefore adopted a conservative attitude when publishing details of the luminous range. It was their practice to quote figures for the average weather conditions to be expected in any given district. He also suggested that, in addition to observations on the visibility of standard objects, work should be done with objects of differing shapes. M. Baldino also felt that the subject was too complicated to be reduced to a simple chart and suggested more tests before acceptance. Dr. Hampton, however, pointed out that the only way to give mariners useful information was to give it in a simple form. Moreover, detailed information regarding the many factors involved could not be measured by the navigating officer of a ship, so more complicated calculations were in any case impracticable. He reminded the conference that the tests reported at the Warsaw Meteorological Conference in 1935 showed a correlation between theory and measurement of 2 : 1, which was very good indeed for work of this type.

Mr. Laycock, of Australia, suggested that a further simplification was possible by giving a table covering only three visibility conditions, good, medium and poor, whilst M. de Rouville made a final suggestion for helping the mariner by reporting some promising experiments in which the intensity of the light had been varied automatically to compensate for changes in atmospheric transmission, thus maintaining the luminous range at a constant value. There was, however, a need for a method of varying the intensity of a source from one candela to 10,000,000 or more.

Another interesting paper was by Hampton and Willott, who had investigated the similarity between the transmission of sound and light and found that both are affected by absorption and diffusion, by reflection and refraction. These facts are fully appreciated for measurements on light, but not, apparently, for sound and the authors showed how the same principles should be applied for both. An outline was given of a method of measuring the polar distribution of a sound signal and proposals made that the performance of a sound signal should be given in terms of its source intensity rather than in terms of observed range. Before this can be done, however, the authors recognised that much more work will have to be done on the effect of atmospheric conditions on sound transmission. A French delegate said that some of his work supported the conclusion arrived at, but other workers in France had obtained contrary results. It was agreed that much more experimental data were necessary.

Lighting Exhibition at the Congress of Ophthalmology

A lighting exhibition was arranged by the I.E.S. as part of the recent gathering in London of ophthalmologists from all parts of the world. The exhibition is described below.

The sixteenth International Congress of Ophthalmology, which met in London from July 17 to 22, was the first of these congresses to be held in this country during the present century; it was notable also as being the first to include in its programmes a specially arranged Lighting Exhibition. The Congress was attended by some 1,200 members and about 800 associate and scientific associate members coming in from 65 countries. Nearly 200 of the members had been nominated as official representatives of the different countries, or of universities or ophthalmological societies in these countries. The Congress, of which Their Majesties the King and Queen were patrons, was opened by His Royal Highness the Duke of Gloucester. The president of the Congress was Sir Stewart Duke-Elder, K.C.V.O., M.D., D.Sc., F.R.C.S., and the secretary-general was Mr. Frank Law, M.A., M.D., B.Ch., F.R.C.S., who is president of the Faculty of Ophthalmologists in this country.

The Lighting Exhibition occupied the whole of the Public Health Museum in the London School of Hygiene and Tropical Medicine at Keppel-street, W.C., and its preparation involved evacuation of the contents of the museum and a temporary structural transformation of the interior.

The exhibition was organised by a small group of well-known members of the Illuminating Engineering Society who were nominated by the Council. This group in-

General view of exhibition showing I.E.S. publications stand and some of the exhibits by Mr. H. C. Weston's research group.

cluded representatives of the E.L.M.A. Lighting Service Bureau and the British Electrical Development Association, and these organisations defrayed practically the whole of the expenses incurred in staging the exhibition and in supplying every delegate to the Congress with a printed catalogue.

The exhibition was well attended, and it excited considerable interest among members of the Congress, to whom it afforded an opportunity for appreciating modern methods and standards of lighting and their role in preventive ophthalmology. Among the first visitors on the opening day were the Minister of Labour, the Rt. Hon. George Isaacs, M.P., and H.M. Chief Inspector of Factories, Mr. G. P. Barnett, who were conducted round the exhibition by Mr. H. C. Weston.

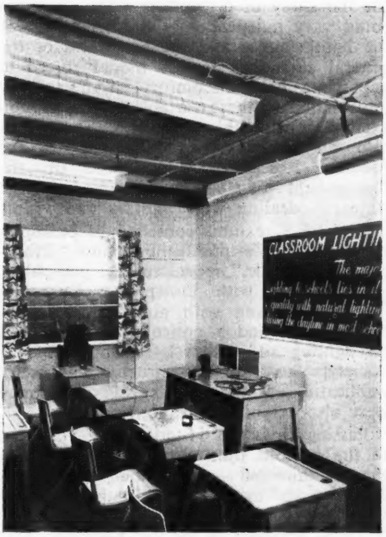
The exhibits were of three categories. Most of those in the first were designed to present pictorially, or by models, some of the results of modern researches concerned with adequacy and suitability in lighting. The exhibits illustrating applied lighting practice formed a second category, while in the third were the exhibits of lamps and lighting equipment.

In the section devoted to "lighting fundamentals" were shown some striking wall diagrams summarising Lythgoe's work on the relation between illumination and visual acuity. The results of Weston's investigations of the variation of visual performance as illumination, size and contrast are varied were similarly shown. Other wall diagrams showed the results of McDermott's investigation of the daylight illumination necessary for clerical work, and the relation between illumination and accuracy in typesetting found by Weston and Taylor. The effect of illumination on the output of silk-weavers, type-setters and tile-pressers was shown by self-luminous models, as also was the deleterious effect of glitter upon the work of cartridge-case examiners. Also among the exhibits in this section was an ingenious "robot," to wit, a pair of artificial eyes, which responded to changes of illumination of the print they were "reading" by changing their viewing distance. Thus, when the illumination was very low, the eyes closely approached the work, and, as they were pierced by metal rods representing the visual axes, the amount of convergence the ocular muscles would be called upon to produce could be appreciated, and it was shown numerically on a suitable scale, together with the degree

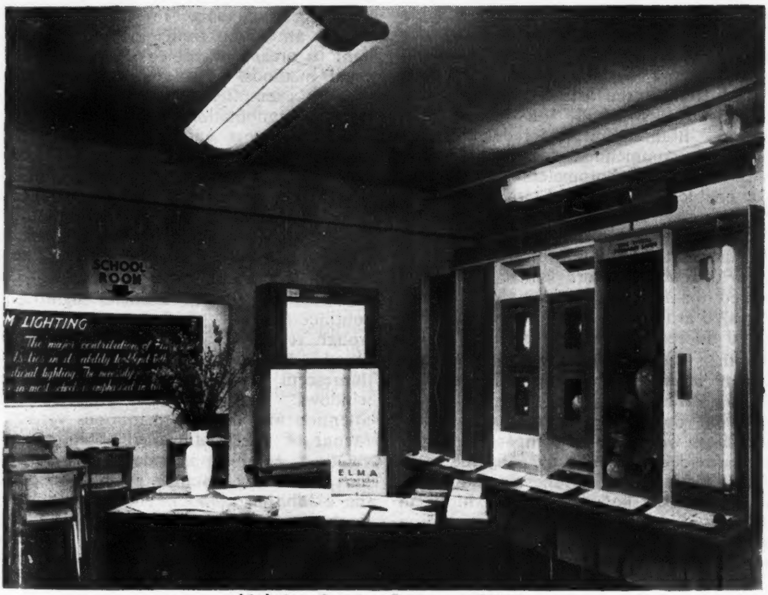
Domestic lighting section.

of accommodation of the eyes. When the illumination was increased the eyes withdrew to a more comfortable viewing distance. The actual values of illumination when the eyes were at the nearest, the intermediate and the most remote viewing distances, were shown by a colour light indicator. Other exhibits included a luminous "monthly expectation of adequate daylight indicator," a luminescent model of the I.E.S. Illumination Chart and a working model showing the effect of illumination on the speed of vision. All the foregoing exhibits were prepared and loaned by the Medical Research Council's Group for Research in Occupational Optics at the Institute of Ophthalmology.

The "fundamentals" section also included two exhibits of the Building Research Station. One of these was a model of the Birmingham City Art Gallery as it will appear when reconstructed; the model was exhibited under an artificial sky so as to demonstrate the day-lighting of the pictures. A fuller description of this was given in an article published in LIGHT AND LIGHTING last month. The other exhibit was a simplified demonstration model of the apparatus being used by Dr. Hopkinson



Classroom exhibit by the B.R.S.



Lighting Service Bureau exhibit.

for the study of discomfort glare. Visitors could vary independently the brightness of the light sources and the brightness of the general surrounds in the model so as to appreciate how discomfort is affected by the relation of these variables. This exhibit excited considerable interest. There was also an exhibit of publications of the Medical Research Council and of the Department of Scientific and Industrial Research dealing with lighting and vision.

The I.E.S. exhibit consisted of examples of the Society's publications, the "Transactions," "Code," reconstruction pamphlets, etc., together with LIGHT AND LIGHTING, literature dealing with aims, objects, and membership, and a notice of recent books on lighting and vision by members of the Society. Some of the instructive and useful publications of the Lighting Service Bureau were also exhibited on another stand.

Passing from the "fundamentals" section to the exhibits illustrating lighting practice, the illuminated schoolroom was very effective, and many of the ophthalmological visitors showed great interest in it. The main features, designed by Mr. W. Robinson, who also played a leading part in organising the whole exhibition, was a variable brightness artificial sky by which natural lighting of the schoolroom through a wall window was simulated. Fluorescent tubes and suitable dimming equipment were used. The sky brightness could be varied by the visitor, and a photo-electric lighting control unit was installed so that the artificial lighting was automatically switched on when the "natural" illumination was reduced below the level recommended for school classrooms. Portable photometers on different desks enabled the daylight gradient to be demonstrated. A dark-green chalk-board, mounted on a pale primrose-coloured wall, was illuminated by fluorescent tubes in angled opaque reflectors which completely screened the lamps from the view of anyone seated at the desks. For general lighting, louvred fluorescent units were installed.

Another section of the exhibition was devoted chiefly to a demonstration of operating theatre lighting. A five-tube fluorescent operating-table unit was shown and visitors were able to compare the lighting it provided with that given by the more familiar circular single tungsten lamp unit which was also shown. Other exhibits in this section included high intensity Xenon flash tubes and complete photographic lighting equipments embodying these tubes. Of special interest was a circular flash tube designed to encircle the camera lens, this device being particularly suitable for ocular photography.

Passing to the next section visitors found domestic lighting exemplified in a well-lighted furnished sitting- or waiting-room. Here one wall was equipped with tungsten wall-lighting units of simple but tasteful design. In the opposite wall a curtained window was attractively lighted by a fluorescent tube concealed behind the pelmet. Various more or less decorative fluorescent units for ceiling mounting were demonstrated, and the whole appearance of the room, with its light decorations, modern furniture by Heal and Sons, and its liberal illumination, was generally admired. Floor standard and table lamps were also shown, including a table lamp complying with the British Standard Specification for reading lamps. Comparison was made of the performance of this lamp and that of a typical "decorative" table lamp. The superiority of the BSS type was readily appreciated by visitors, although not a few of them remarked that the example shown was of insufficient aesthetic merit.

Next to the domestic lighting exhibit a factory section was arranged. This section was illuminated by a selection of industrial fluorescent units, but there was also a representative exhibition of tungsten lighting units, including some for local lighting, as well as an exhibit showing the "piping" of light to areas difficult to illuminate by the usual methods. Two opposite walls were used to exemplify factory colour schemes, and the combination of good colouring of factory interiors and machines with good lighting was further illustrated by colour photographs. Two illuminated dioramas, constructed with the aid of actual colour photographs of the Foots Cray radio valve factory of Messrs. Standard Telephones and Cables, were also exhibited, so that comparison could be made between a conventional system of artificial lighting by continuous rows of fluorescent lamps in trough reflectors and a system of "naturalised" artificial lighting by means of fluorescent lamps mounted behind mock windows. These dioramas attracted much attention and drew a unanimous verdict in favour of the "naturalised" lighting.

Other exhibits included a section of louveral ceiling installed at the entrance to the exhibition, a comprehensive display of discharge lamps, and the E.L.M.A. Light-Sight Tester which showed numerous oculists that the illumination of their choice for reading was generally much higher than they supposed it to be!

Lighting Costs

By W. ROBINSON, B.Sc., A.M.I.E.E., F.I.E.S.

Describing a method of assessing and comparing the cost of lighting by both tungsten and filament lamps.

The introduction of high efficiency lamps requiring auxiliary control equipment emphasises the question of the overall lighting cost of installations using these light sources in relation to lighting costs with incandescent lamps in installations giving equal illumination. A convenient method of establishing cost comparisons of this sort is by the use of equal-cost curves which show the service conditions at which equivalent lighting installations using different light sources have the same annual lighting costs.

Such curves can be drawn from a simple formula :

Let A = annual capital charges (labour in upkeep and capital depreciation)

L = cost of lamps per 1,000 hours' burning

H = thousands of hours' lighting operation per annum

W = gross lamp watts

C = cost of electricity per kWh.

T = charge per kW. of installed load (or maximum demand)

Then the total annual cost of lighting is:—

$$A + LH + WHC + \frac{TW}{1000} \text{ (using the same monetary units throughout)}$$

If we consider this expression applied to two installations under comparison and distinguish the separate factors by suffices :—

f — applying to fluorescent or other high efficiency light source

t — applying to tungsten filament lamps or other lower efficiency source

then the two installations have the same annual cost when :—

$$A_f + L_f H + W_f HC + \frac{TW_f}{1000} = A_t + L_t H + W_t HC + \frac{TW_t}{1000} \quad \ldots\ldots 1$$

The particular cost of current at which this condition arises can be found by solving the equation. Let this cost of current be c:—

$$cH(W_t - W_f) = (A_f - A_t) + H(L_f - L_t) + \frac{T}{1000}(W_f - W_t)$$

Let $W_t - W_f$ = W_d, the *saving* in wattage by high efficiency lamps

$A - A_t$ = A_d, the *extra* annual capital charge with high efficiency lamps

$L_f - L_t$ = L_d, the *extra* lamp cost per 1000 hours' burning of high efficiency lamps

$$\text{Then: } cHW_d = A_d + HL_d - \frac{TW_d}{1000}$$

$$c = \frac{A_d}{W_d H} + \frac{L_d}{W_d} - \frac{T}{1000H} \quad \ldots\ldots\ldots\ldots 2$$

If electricity is taken on a flat rate, T = O and the expression simplifies to:—

$$c = \frac{A_d}{W_d H} + \frac{L_d}{W_d} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Equation 2 is a universal expression giving the boundary cost of current (c) at which any two lighting installations under the same operating conditions have the same overall annual lighting cost. The cheaper of two lighting installations is then simply determined by comparing the actual cost of current (C) with the boundary cost of current (c) obtained from equation 2 or 3.

If (C − c) is + ve: High efficiency lamps give cheaper lighting despite higher capital, etc., costs.

If (C − c) is − ve: Low efficiency lamps give cheaper lighting.

The diagrams relate to the annual cost of light from an 80-watt fluorescent lamp and a 200-watt tungsten filament lamp, and have been drawn from values of c in the boundary formula corresponding to a range

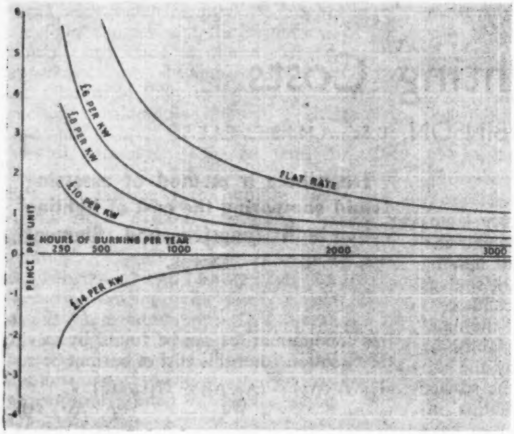


Fig. 1. Curves showing operating conditions at which an 80-watt fluorescent lamp and a 200-watt tungsten filament lamp will have the same annual operating cost. Assumed life of capital equipment for write-off purposes—ten years.

of values of H and using the data in Table I.*

The curves in Fig. 1 for a 10-year write-off period, are derived as shown in Table II.

$$L_d = 62 - 48 = 14$$
$$W_d = 200 - 100 = 100$$
$$A_d = \frac{1392 - 0}{\text{write-off period}} = 139$$

* Data used in the examples were applicable at the time of drafting but are not necessarily correct at the time of reading.

The curves in Fig 2 show corresponding results for a 5-year write-off period.

The curves are used as follows:—

From a point on the horizontal co-ordinate representing the actual annual burning hours of the installation in question, take a vertical to cut the curve appropriate to the actual tariff charge per kW. of installed load, which may be in the upper or lower part of the diagram. Take a horizontal from this point to the vertical co-ordinate and read off the current cost in

Table I.

	Fluorescent	Tungsten
Cost of lamps	15s. 6d. = 186d.	4s. = 48d.
Life of lamps	3,000 hours	1,000 hours
Cost of lamps per 1,000 hours in pence (L)	62d.	48d.
Typical cost of associated equipment (excluding lamps)	£5 16s. = 1,392d.	nil
Wattage	100 (allowing 20-watt gear loss)	200

Table II.

H	$\frac{L_d}{W_d} + \frac{A_d}{W_d H}$	$\frac{T}{1000H}$ where T = (per kw)					c (Flat Rate)	c (when T =)				
		£6	£8	£10	£12	£14		£6	£8	£10	£12	£14
0.5	0.14 + 2.78 = 2.92	2.88	3.84	4.8	5.76	6.72	2.92d	0.04d	—0.92d	—1.88d	—2.84d	—3.8d
1	0.14 + 1.39 = 1.53	1.44	1.92	2.4	2.88	3.36	1.53d	0.09d	—0.39d	—0.87d	— 1.35d	— 1.83d

pence per unit at this point. This value represents the boundary cost of current at which both lamps have the same overall annual running cost and which may be positive or negative. If the *actual* current cost (necessarily positive) is greater than this value, fluorescent lighting is cheaper and vice versa.

Alternatively from a point on the upper part of the vertical co-ordinate representing the *actual* current cost take a horizontal to meet a vertical from a point on the horizontal co-ordinate representing *actual* annual burning hours. If the point of junction of the two lines lies above the appropriate tariff curve, fluorescent lighting is cheaper and vice versa.

For particular cases it is, of course, only necessary to work out the boundary formula for the particular number of operating hours and the tariff charge in question, but an equal-cost curve can be very useful for determining the effect of changes in operating conditions such as tariff charges or an alteration in lighting hours due to the introduction of night shift, etc. Once the boundary cost of current has been determined the overall annual gain, or profit, is obtained by evaluating the expression

$$W_d H\ (C - c) \quad \ldots\ldots\ldots\ldots 4$$

Alternatively the period over which running savings from high efficiency lamps will recoup the extra capital cost can be determined as follows:

$$\text{Recoupment period} = \frac{\text{Extra initial cost}}{\text{Annual running savings}}$$

The annual running savings are:

Electricity — represented by $(W_d HC)$

Lamp Replacement — represented by $(-\ L_d H)$

Load or M.D. charges — represented by $\frac{TW_d}{1000}$

The expression then becomes:—

$$\text{Period of recoupment} = \frac{\text{Extra initial cost}}{W_d HC - L_d H + \frac{TW_d}{1000}}$$

$$= \frac{\text{Extra initial cost}}{W_d H\left(C - \frac{L_d}{W_d} + \frac{T}{1000H}\right)} \quad \ldots\ldots\ldots 5$$

The term $\left(C - \frac{L_d}{W_d} + \frac{T}{1000H}\right)$ can be termed the operating coefficient whence the period required for recoupment of the extra initial cost associated with high efficiency lamps becomes:—

$$\frac{\text{Extra initial cost}}{\text{Annual kWh. saving} \times \text{operating coefficient}}$$

Use of Equal-Cost Curves

As an example of the use of the curves, we may consider the annual lighting cost of the 80-watt fluorescent and 200-watt filament lamp on which the curves in Figs. 1 and 2 are based.

Assuming that either lamp will be in operation for 1,500 hours per annum and the fluorescent control gear has a life of 10 years, then from the curves in Fig. 1 we find that the cost per unit at which the two

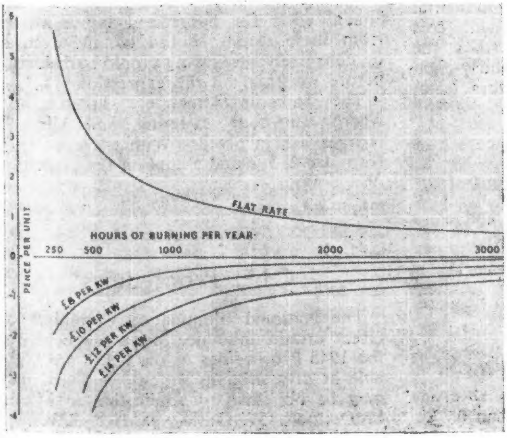


Fig. 2. Equal cost curve as Fig. 1 based on an assumed life of capital equipment for write-off purposes of five years.

lamps will have the same annual cost (c) is 1.1d. in the case of a flat rate, or − 0.15d. if the kW. charge is £8, or − 0.8d. if the kW. charge is £10, etc.

The actual charge paid (C) is then compared with the appropriate value of the boundary cost, c. If, for instance, the actual cost of current is 1½d. per unit, and there is no tariff charge, then :—

(C − c) is + ve and the fluorescent lamp is cheaper to run.

The overall annual saving

$$= W_dH\ (C - c)$$
$$= 100 \times 1.5 \times 0.4$$
$$= 60\text{d.} = 5\text{s. per lighting point.}$$

The period required to recoup the extra capital cost is

$$\frac{£5\ 16\text{s.}\ 0\text{d.}}{W_dH\left(C - \frac{L}{W_d}\right)} = \frac{1392}{100 \times 1.5 \times (1.5 - .14)}$$
$$= 6.8 \text{ years.}$$

If a load charge of £8 per kW. installed is imposed the appropriate value of c becomes negative (− 0.15d.). This means literally, that filament lighting could only show a profit over fluorescent lighting if the consumer were paid 0.15d. by the electricity suppliers for every unit of electricity consumed in lighting during the 1,500 hours of operating time.

The preceding formulæ can be applied using total costs rather than individual lamp costs and the following example compares the lighting costs of two alternative schemes designed to produce equivalent lighting conditions:—

Assume that the write-off period is 10 years, that the installation burns for 1,500 hours per year, that the filament scheme involves forty 200-watt lamps in industrial diffusing reflectors (total equipment cost without lamps, say, £140), and that the fluorescent scheme involves thirty-eight 80-watt lamps in trough reflectors (total equipment cost, without lamps, say, £320).

$$\text{Then } c = \frac{L_d}{W_d} + \frac{A_d}{W_dH} - \frac{T}{1000H}$$

$$L_d = \frac{186 \times 38}{3} - 40 \times 48 = 2356 - 1920$$
$$= 436 \text{ pence}$$

$$W_d = 8000 - 3800 = 4200 \text{ watts}$$

$$A_d = \frac{320 - 140}{10} \times 240 = 4320 \text{ pence}$$

$$H = 1.5$$

If T = 0 (i.e. flat rate)

$$c = \frac{436}{4200} + \frac{4320}{4200 \times 1.5} = 0.105 + 0.685$$
$$= 0.79 \text{ pence}$$

i.e., at any cost of current more than 0.79d. the fluorescent scheme will be cheaper to operate on a flat rate electricity tariff.

The net annual gain by using high efficiency lamps is $W_dH\ (C - c)$, and if current is taken at a flat rate of 1½d. per kwh. the net profit by using fluorescent lamps is :

$$4200 \times 1.5 \times (1.5 - 0.79) = 4480\text{d.}$$
$$= £18\ 13\text{s.}\ 4\text{d. per annum.}$$

The period over which running savings will repay the extra capital cost of fluorescent lighting is given by formula 5 :—

$$\text{Period of recoupment of extra capital outlay} = \frac{(320 - 140)\ 240}{4200 \times 1.5\ (1.5 - 0.105)}$$
$$= 4.9 \text{ years.}$$

If, on the other hand, there is a kilowatt charge of £10 :—

$$c = 0.79 - \frac{10 \times 240}{1500} = 0.79 - 1.6$$
$$= -0.81 \text{ pence}$$

i.e., for an operating period of 1,500 hours per year, fluorescent lighting will be cheaper whatever unit charge is made for electricity. If the current is supplied at ¾d. per unit :—

Net saving by using fluorescent lamps = 4200 × 1.5 × (0.75 + 0.81) pence = £41 per annum.

$$\text{Period of recoupment of extra capital outlay} = \frac{(320 - 140) \times 240}{4200 \times 1.5\ (0.75 - 0.105 + 1.6)}$$
$$= 3 \text{ years.}$$

It should be noted that the costs of wiring and of annual maintenance have been assumed to be equal for both systems. In practice this may not be so and the extra annual costs for fluorescent lamps arising from these causes should be added to A or, conversely, any saving should be deducted, before working out the expression.

The foregoing treatment applies only where watt-hour metering and kilo-watt charges are involved. With kVA metering formulae 2, 3, 4 and 5 apply if the expression $\frac{W_t}{\text{p.f.}_t} - \frac{W_f}{\text{p.f.}_f}$ is substituted for W_d.

C.I.E. Proceedings

The National Illumination Committee of Great Britain announce that a few copies of the 1948 Proceedings of the C.I.E. are available at fifty shillings a copy, and that they may be obtained on application to Mr. L. McDermott, 57, Onslow-gardens, S.W.7.

Problems in Illuminating Engineering For Students

By S. S. BEGGS, M.A., F.I.E.S.

12. *Lighting Economics and Conclusion*

The only other section of the syllabus which we shall be able to consider is that concerning the economics of lighting. This is an important section, to which often too little attention is paid, although obviously the ability to make a sound judgment of the quality of a product, to determine the performance of equipment, or to make a correct assessment of the real cost of a project, so that the *best* lighting be provided is a very desirable quality of a trained lighting engineer. Most of the previous sections of the syllabus form a foundation for the requisite knowledge, for technical considerations must determine the basis of comparison. The student must learn in addition how to make reliable tests of the equipment, what standards and specifications exist, the order of the costs of material and equipment used in illuminating engineering, how to plan for proper maintenance of an installation, and how to assess the true value of a device or scheme. A brief reference to some of these considerations was made in the answer to Question 21, on the preference for various electric lamps for street lighting. At this stage it is not necessary to learn exact values, but to have a knowledge of the different items to be considered and of factors affecting their relative importance.

The economic value of good lighting should be appreciated, and a brief review made of the results of controlled operational trials. A good knowledge should be gained of the contribution to the real cost of an installation of the various individual charges, and of schemes to effect the most economic arrangement. The booklet, "Modern Factory Lighting," published jointly by the British Electrical Development Association and the E.L.M.A. Lighting Service Bureau, is useful in presenting a picture of these aspects of industrial lighting.

Methods of testing equipment and the organisation of a testing department (including life tests) also come within this section of the syllabus.

Some acquaintance with methods of power supply is necessary, although this need not be detailed, as it rightly comes within the province of the electrical or gas engineer; similarly the student should know of the existence of regulations, specifications and codes relating directly or indirectly to lighting, and a broad outline rather than detail of their contents.

This is the final article of this series, the first of which appeared in Vol. XLII, No. 9, September, 1949.

Question 22 (1941)

Discuss carefully the question of the proper maintenance of the whole of the lighting equipment of a large factory, consisting of offices and machine shop. Show that the proposals outlined are economically sound.

Answer

Proper maintenance of the lighting equipment is essential for good lighting, i.e., the continued availability of sufficient and correctly distributed light. The value of good lighting economically has been shown by several controlled tests in different industries, varying from relatively rough work such as tile pressing or foundry work to more precise tasks such as lathe work and type-setting by hand. If a good installation is allowed to depreciate the output will obviously be no better than that from a poor installation, and the initial advantage will be lost. The tests indicate that the loss due to fall in output and increased spoilage is likely to be between 5 per cent. and 10 per cent. of the normal production. The cost of the provision of good lighting in a factory works out at about 2 per cent. of the pay-roll, and maintenance accounts for only about one quarter of this. The loss by poor maintenance will therefore be far in excess of the small additional cost required for a proper system of maintenance. Moreover, it represents a much greater proportion of the profit of the undertaking, and may indeed make all the difference between a profit and a loss on the year's working.

In addition to this obvious financial value of maintaining good lighting, there are the psychological and health aspects. Poor

lighting undoubtedly results in more accidents (which directly or indirectly will affect the production rate). Well maintained lighting encourages cleanliness and alertness, and a reputation for congenial conditions attracts the better workers to a firm.

The above considerations apply to almost any lighting installation, and therefore generally throughout a factory. To maintain good lighting attention must be paid to the installation on a regular schedule; haphazard cleaning or replacement of lamps or fittings leads to patchy lighting and dark areas. The equipment should be inspected for damage or faults, and repaired or replaced as necessary. A regular schedule of cleaning should be adopted. The frequency will depend on several factors, and particularly on the location of the factory (e.g., in relatively open country or in a large industrial town) and on the type of work carried out in the section of the factory concerned; it will not necessarily be the same for all departments. The loss of light due to accumulation of dust and dirt on lamps and fittings may be considerable without the equipment looking very dirty. Actual measurements in normal installations of industrial reflectors have shown as much as 50 per cent. depreciation in illumination due to this cause alone. Enclosed diffusing fittings are likely to suffer to as great an extent as open industrial reflectors, and the offices should therefore receive as much attention as the machine shop. It is not possible to state a universal figure for the period between cleaning, but it usually will be three or four months. A periodic check on the illumination provided by each installation should be made and a record kept, from which a suitable cleaning schedule can be worked out. The permitted depreciation should be kept to a minimum, and the variation in use certainly should not exceed $\pm$ 25 per cent. on the average over the period between cleaning.

In order to reduce interruption of normal work to a minimum, maintenance should preferably be carried out at slack periods, or out of the normal working hours. This applies especially where the factory equipment must be taken out of use during this period, for example where maintenance of high mounted fittings is carried out from a travelling crane platform, or overhead shafting forms a source of danger.

The cost of replacing an individual failed lamp may prove very expensive (much more than that of the lamp itself), especially where the fittings are not easily accessible, and a system of group replacement of all lamps in an installation may prove more economical than individual replacement on failure. In such a scheme all lamps are replaced at intervals somewhat shorter (say 20 per cent.) than their rated life, before the number of failures is significant. In effect the cost of the lamp is thereby increased by this fraction; it may be noted that the cost of the installation is not increased by this amount, for the cost of the lamps forms a relatively small proportion of the overall cost of the installation (of the order of 25 per cent. probably), so that the increase is only about 5 per cent. in this cost. Against this must be set the great saving in maintenance cost, from carrying out the complete operation at a selected convenient time. The routine maintenance costs are normally of the same order as the cost of lamps, and the saving on this charge is likely to be considerably more than the 20 per cent. or so required to balance the increased lamp cost. In addition the freedom from interruption of normal business, the slightly higher average light output over the shorter life of the group replacement lamp, and the psychological value of an installation without frequent failures represent savings which are hard to evaluate, but nevertheless are significant and should not be overlooked.

Conclusion

This series of articles has aimed at providing the student (and the teacher, too, if he is not well acquainted with the lighting industry) with a very brief guide to the field to be covered and the relative importance of some of the items for Section B of the Final Grade examination of the City and Guilds of London Institute, and (probably more important) indicating the form of answer that is required. Throughout, it is not so much a wealth of detail that is expected (for in practice that can generally be looked up in a reference book) as a lively appreciation of the factors that bear on a problem, ability to judge their relative importance, and a sense of what does and what does not lead to good lighting in its broadest sense. A sound practical approach to the problem is more important than a vast theoretical knowledge. It is unlikely that the student will have a close acquaintance with the whole of the field of lighting, and he will obviously choose some questions to answer rather than others; but he *ought* to be able, if pressed, to discuss any of them intelligently (if not deeply).

Most of the answers given in the series are fuller than the average student might be

expected to give in the examination; they were intended to indicate as complete and balanced an answer as might be possible within the time available, and particularly to stress the framework of the answer while suggesting lines of thought and other aspects of a problem that might not occur to the student himself. No attempt has been made to provide a complete course, nor even to give a list of reading to be done, for that would be impossible within the scope of this series. Unfortunately there is no book at present published that is eminently suitable as a text-book for this examination. A number can usefully be delved into, and much of the information is contained in published papers, although these naturally tend to be rather fuller than the student requires. The Illuminating Engineering Society is the main centre for the exchange of information on lighting matters, and its various publications should be of considerable assistance to him.

In concluding this series, I should like to acknowledge the help I have had from my colleague Mr. C. A. Foxell in the preparation of the diagrams illustrating some of the answers to questions.

Lighting in Beverley Minster

The electric lighting installation at Beverley Minster (LIGHT AND LIGHTING, Vol. XLII, No. 7, 1949, page 174) has now been completed by the installation of the choir lighting fittings illustrated on page 282. This completes a lighting installation which has created considerable interest both in this country and abroad.

The main lighting installation is carried out with 5-ft. warm white fluorescent lamps located between adjacent shafts of the pillars. In all, 72 fluorescent lamps are used, the entire installation in the nave, aisles and transcepts being controlled from a panel in the verger's pew.

The choir lighting fittings, of which there are six in all, were specially designed and made by Mr. S. J. Kerrswill, A.R.C.A. They consist of oak standards supporting octagonal bronze vase-shaped fittings, each of which contains a 200-watt lamp. The flat octagonal reflector, having its internal surface rendered matt-white, contains diffusing glass on its lower side, while ventilation is provided by a series of holes which permit a current of air to pass through the fitting. Each choir lighting fitting is controlled separately by a switch located below the book-rest of the choir stall.

These special fittings are designed to be in keeping with the supporting columns of the canopies and tabernacle work above the rear choir stalls, which date from the early part of the sixteenth century. The choir seats are 68 in number and form a magnificent series of examples of ancient woodwork.

The main switchboard for the installation consists of a polished bakelite panel on which is engraved in white a plan of the Minster showing the location of all the lighting fittings. Switches are mounted on the panel to indicate the lighting fittings they control, and it is thus possible for any combination of lights to be readily selected. The main control panel is mounted on an angle iron frame, and all cables enter through the bottom of the switchboard. Master switch-fuses and associated distribution boards are fitted underneath the panel. All work in connection with the design and execution of the lighting installation was carried out by the staff of No. 6 (Hull) Sub-Area of the Yorkshire Electricity Board.

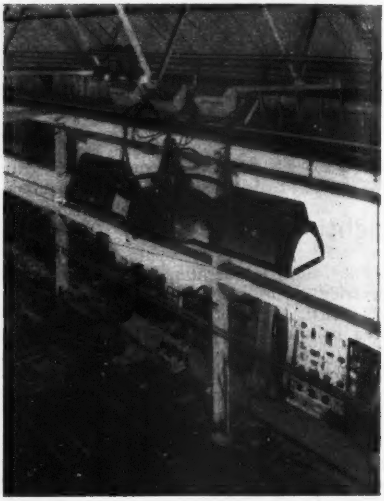
New Lighting Installations

Blended Lighting in a Foundry

A scheme using blended lighting units has recently been put into operation in the foundry of Messrs. Dawson, Bentley and Co., at Keighley. Each unit houses one 1,000-watt tungsten lamp together with two 400-watt MA/V mercury vapour lamps, giving an average illumination in service of 20 lumens per square foot. The mounting height is 20 ft. A noteworthy point is that the highly concentrated light penetrates right down into the casting boxes in the floor of the building.

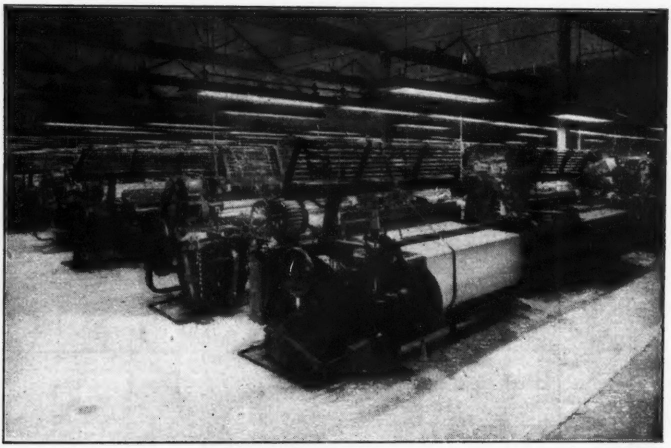
These blended light units, using a combination of tungsten and mercury vapour lamps, were designed by the BTH Co., with a particular view to their use in factory areas where the need for a good general level of illumination has to be reconciled with conditions which make a medium to high mounting height equally necessary.

Contractors for this installation were Messrs. Bancroft and Tordoff, of Keighley.



(Above). Close up view of fitting looking down towards the floor of the foundry.

(Left). General view of the foundry.



Part of the weaving dept. at the Albion mills, Greengates, Bradford, where a total of 386 Revo "Trufolite" fluorescent fittings have been installed.

(Left). Lecture theatre at the nurses' home, St. John's Hospital, Lewisham.

A Small Lecture Theatre

The excellent appearance of the interior of the lecture theatre in the new extensions to the nurses' home at St. John's Hospital, Lewisham, is upheld by the installation of lighting equipment in keeping with the general surroundings.

The lighting for the theatre itself is provided by decorative lighting fittings mounted in continuous pairs. The lighting of the blackboard is by means of two special blackboard fittings designed to give even illumination over the blackboard and at the same time to avoid glare.

The lighting was planned by the illuminating engineering section of Thorn Electrical Industries, Ltd., and was installed by Hayden Electrical, Ltd.

Showing the arrangement of lighting fittings at the Lapointe factory, Watford By-Pass.

Fluorescent Lighting in a "Barrel Vault" Roof Installation

The new factory for the production of broaches and broaching machines of the Lapointe Machine Tool Co., Ltd., at Bushey, on the Watford By-Pass, is built on modern architectural principles, by which a ground floor area completely free from piers, columns or other obstructions is obtained. The roof has no support except the outer walls, and is formed in a series of "barrel" vaults. Each bay spanned by a vault is 90 ft. wide and 30 ft. deep, and the main production area on the ground floor consists of eight such bays.

Fluorescent lighting is installed in all the ground floor bays, each of which is equipped with two continuous rows of trough reflector fittings mounted direct on the reinforced concrete ceiling a short distance below the apex of the vaulting on each side. The top of each vault is occupied by a glazed lantern for daytime illumination of the factory.

By mounting the fittings on the ceiling, the accumulation of dust on their tops is avoided—an important feature considering their height of some 24 ft. above floor level. At the same time the freedom of the roof area in each bay from any type of projecting support is maintained so that the architect's conception of the building is effectively preserved in practice.

By night the ceiling area of each bay acts as a reflector, and is evenly illuminated over its whole surface by the light emitted through the sides and tops of the white opal reflectors, the reflectors being spaced slightly away from the ceiling by the gear channels of the fittings. Illumination on the working plane averages 25 lumens per sq. ft. There are 24 fittings per bay, or a total of 192 in the whole installation.

Five 100-w. tungsten fittings are also mounted in each bay between the fluorescent lamps, and are controlled by contactor type switches conveniently located along the night watchman's patrol route so that he can have lighting for his inspections without switching on the main fluorescent installation.

The type of product on which the factory is engaged is long and thin in outline, and is not suited to mass production methods. Good lighting for the operatives was therefore particularly important, and has been successfully achieved by the continuous rows of lamps in conjunction with the reflector effect of the ceiling. The installation is another example of how successfully fluorescent lighting may be fitted in with the most modern forms of factory design and layout.

The electrical installation was carried out by Barlow and Young, Ltd.

Correspondence

Fittings Design

To the Editor of LIGHT AND LIGHTING

Sir,—Your issue of June, 1950, contains an editorial on "Fittings Design," in particular reference to the 1951 Stock List, and as shown in the Council of Industrial Design's recent exhibition of Home Furnishings.

It is only to be expected that the C.I.D.'s choice will be subject to criticism, some justified and some not, and writing as a designer it seems to me to be a good thing that this should be so, for we can only do a useful job in the production team if we avoid an attitude of "you will have this." Good criticism and a lively interest in other branches of design will keep our outlook broad and our minds receptive to new ideas. But talking of this question of what "we would care to live with." It depends who "we" are, or think we are, or even wish we were, and again upon how we do live, wish to live, or wish we had lived. So it would seem from the things people do, in fact, live with.

The fittings industry has produced some first-class design work, more especially in the industrial, commercial, and street lighting branches, to name only three spheres. In these cases the designer has approached his problem with a clear brief, and his design has been a logical one, giving due regard to questions of performance, materials, and production.

During this process no one has even whispered that the result should be "decorative," but should they do so, the chances are that things will start going wrong. Fluorescent fittings will have their end plates stamped with some meaningless and useless ornament. Then, more especially if the thing is to be used in the home, the electric lamp will be put into fancy dress, and will appear encased in a metal or cardboard tube (dripping with imitation wax) and surmounted by a little hat. Then, accompanied by two, or perhaps more, equally unfortunate lamps, this odd assembly will be united with a bad reproduction chandelier form. To enjoy to the full the absurdity of the situation, let us take the thing further and sell nylon wigs and rayon period suits to go with it. These and other things go on side by side with good honest design within the same organisation.

The domestic section of lighting design has been hindered by several things. It has been tied to a furnishing trade which, with some notable exceptions, has produced "reproduction" and jazz modern for many years. Furthermore, certain limiting factors have been imposed by house wiring systems which have tended to show little regard for individual planning needs, have provided too few plug and bracket points, and have completely ignored built-in lighting. But, nevertheless, domestic fittings in general continue to show a deplorably high proportion of badly conceived and made examples of the sort of nonsense described above. If this is the kind of thing that it is thought people wish to continue to live with, then it would seem that the fittings industry underestimates the outlook of its future patrons, and it underlines the necessity of the good work the C.I.D. is doing in influencing its present public.

The final paragraph of your comment laments the tendency to "perpetuate the Utility designs of recent years; which is hardly setting a high standard, or we think influencing the public along the right lines."

The Utility range in furniture was probably the best design (but not necessarily the best materials or workmanship) at a modest price which has ever been offered to the public. It was designed by a panel of designers of ability and good judgment, and it was shorn of all pretence of being something which it was not. All good design should be related to the social and economic background of the times, and the post-war contemporary movement is no exception. To take past successes out of their context and try to reproduce them in our own age is to march backwards.

By encouragement, fair criticism, and an understanding of human needs, we shall slowly progress. We shall also be "influencing public taste along the right lines." Perhaps, too, it will be found that good design pays better than the bad, and then everyone will be happy.—Yours, etc.,

MARTIN BARNICOT, M.S.I.A.

Guildford, Surrey.

Personal

The Benjamin Electric, Ltd., announce that Mr. H. G. Campbell, Assistant Managing Director, has now been appointed Joint Managing Director of the Company.

Trade

Cryselco, Ltd., announce that, as from September 1, they are opening a new depôt at 34-40, Bath-street, Sneinton Market, Nottingham, where comprehensive stocks will be carried for the convenience of the trade.

POSTSCRIPT

By "Lumeritas"

Some of my readers will have noticed, recently, a reference in the daily Press to Lumena. This is not the female of the species Lumen, and no one need hastily deplore the arrival of yet another technical term! However, Lumena is certainly feminine. It is the name given to an ingeniously constructed life-size transparent model of a woman complete with internal organs, vascular system, and so on. It has been created for instructional purposes, and includes several hundred yards of wiring and numerous miniature lamps. So, Lumena is not inaptly named, and she is to make her debut on August 29 at the British Food Fair, to be held at Olympia.

In the June issue of our American contemporary, "Illuminating Engineering" there is an article on "Lighting Design for Night Driving," in which the author uses the term "luminosity" instead of "brightness" and expresses values of luminosity in lumens per square foot. But luminosity is now defined as subjective brightness, and the proper term for photometric brightness —which, in the case of a uniform diffuser, can be expressed in lumens/ft.^{2}—is "luminance." It seems a pity that confusion should still be caused by failure to adhere to an agreed terminology. I am pleased to note, however, that the same author also expresses illumination in lumens/ft.^{2}, which is in accordance with current British practice.

These are busy times, and wishing to relight one of my rooms at home without consuming my own time I decided to approach a local contractor to do the work. I must admit, however, that my decision was also dictated by curiosity to discover what service I could expect. Since my local branch of the Electricity Board habitually inform me, per "stick-on" attached to my quarterly account, that complete installations can be undertaken, I sought their advice first. I wished, I said, to relight a room which I use as a study; what would they recommend? What general illumination should I have, what illumination ought I to have on my desk, and how would they suggest these requirements should be met? I was asked the dimensions of the room and then told that a 100-watt lamp suspended "as usual" from the centre of the ceiling in anyone of several "fittings" to be seen in the showroom should be satisfactory. As to the desk, they had a good selection of table standards from which I could take my choice, and one of these equipped with a 60-watt lamp ought to be all right. "But," said I, "what illumination will I get? I understand there is a code of recommended values of illumination for different purposes; what is the value recommended for my purpose, and will you measure what you give me so that we both know I have what I ought to have?" This was too much to ask. The representative dealing with me had not heard of the code I mentioned; had I seen it myself, and where did it come from? "The Illuminating Engineering Society," said I. "Oh," said he, "is there one? I didn't know. Anyway, we don't measure illumination, but you can take it from me that everything will be all right if we do the job for you." I said I would think over his suggestions, and then proceeded to the most flourishing independent local contractor to try my luck with him. Alas, it was no better. A rather more ornate and expensive pendant fitting was recommended to me, and a further choice of table standards offered, but I was told, "we go by watts, you know, we haven't seen the code you speak of; yes, I think I've heard there is an Illuminating Engineering Society, but I'm not a member; we know by experience how to light a room; no, we can't show you any examples in LIGHT AND LIGHTING—didn't know there was such a paper—but I'm sure you'll be pleased with the job if we do it for you." Is this sort of thing typical or exceptional? I rather think it is typical, and I find it rather depressing.

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